The Impact of Cochlear Implantation on Phonological Awareness in Deaf Children

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ABSTRACT

In recent years, it has been reported that cochlear implantation (CI) benefits deaf children's speech perception, language development and speech production. Early fitting of an implant results in improved outcomes. This thesis explores the development and determinants of phonological awareness (PA) in paediatric CI users. Phonological awareness is important for literacy acquisition in hearing children. In hearing children phonological awareness develops first at the syllable level then at the intra-syllabic level of onset-rime and finally at the phoneme level. It is expected that paediatric CI users will follow the same developmental trajectory. The impact of the timing of cochlear implant fitting on phonological awareness and the relationship between phonological awareness and word reading are also investigated.

Three new tests of phonological awareness were developed for the thesis. Nineteen children with implants were seen twice over a 12 month period. Nine of these children were fitted with their implant early (below 3.6 years) and ten were fitted later (between 5 and 7 years). Several comparison groups were included; a group of profoundly deaf children with hearing aids, a group of severely deaf children, a group of hearing children with specific language impairment and two groups of typically developing hearing children. One hearing group was matched for reading level and the other group was matched for chronological age to the CI group.

Phonological awareness in CI users developed along a similar trajectory to hearing children. Syllable awareness was equivalent in the CI group to both groups of hearing children, awareness of rhyme and phonemes was significantly delayed, but was equivalent to the profoundly deaf children using hearing aids. The difference between the early and late CI groups on PA performance was small. There was some evidence of a link between PA and word reading, but overall, receptive vocabulary emerged as the most robust longitudinal predictor of reading ability in deaf children.

To Sam

Thank you for your love

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One new skill I needed to acquire in order to complete this thesis was navigation. This presented an enormous challenge to me since I do not know left from right and cannot read a map. I set off on many mornings with a clear idea of my general direction and main routes, but during the last few miles, I often found myself lost. I sought and received help from many passers by, local shopkeepers and policemen.

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Table of Contents

Chapter 3 - Cochlear Implants (CI) for Deaf Children

Chapter 4 – CI Participants in the Study

Chapter 5 – Phonological Awareness in CI Participants

Tables and Figures

Tables

Figures

APPENDICIES

Chapter 1 - Introduction

1.1 INTRODUCTION

Think of a word .... '*deaf*'.

An associative concept might be '*hearing loss*'. This association defines deafness in terms of **impairment**. Deaf people are impaired relative to 'normal hearing people' because they can't hear. Musselman (2000) says that, "language delay - ... is the hallmark of deafness". This defines deafness in terms of **disability**.

When we define deafness as an impairment with resulting disabilities the fitting of a cochlear implant is an appropriate intervention. Cochlear implants attempt to ameliorate the disability, specifically the acquisition of spoken language, by reducing the hearing impairment. However, advocates and members of the Deaf World who view deafness as part of normal human variation and do not consider themselves as disabled see cochlear implants as an attempt to normalise deafness (Lane, 1992; Lane & Bahan, 1998). The fitting of cochlear implants raises ethical questions. If we accept that diversity enriches human society then instead of attempting to normalise deafness, appropriate interventions to attenuate the communication and language disabilities associated with deafness would be to adapt or enhance the environment. There are changes taking place in western society brought about by the E-revolution which offer new opportunities for deaf people, such as the internet and new communication technologies. Whilst these technologies by-pass hearing impairment they are heavily dependent on literacy skills. Whatever perspective on deafness is taken now, perhaps more than ever before, deaf people need good literacy skills to achieve equal rights and responsibilities in society.

However, learning to read poses a continuing challenge for the vast majority of deaf children. Conrad's (1979) survey in England and Wales showed that the average reading age of deaf adolescents when they left school was around eight years. More recent research shows that the literacy attainment of deaf school leavers has not markedly increased in subsequent years (Allen, 1986; Holt, 1994; Marschark & Harris, 1996). Deaf children typically have considerable delays in their understanding and use of spoken language (Bishop, 1983; Moog & Geers, 1985; Marschark, 1993; Paul, 1998) and research indicates that language difficulties are at the root of the reading problems for deaf children. Knowledge of vocabulary emerges as the strongest predictor of reading attainment in deaf children (Fishler, 1985; LaSasso & Davey, 1987; Moores & Sweet, 1990; Paul, 2001). Whereas in hearing children who are learning to read English at least, the strongest predictor of reading development is phonological awareness (Bradley & Bryant, 1983). Phonological awareness is the ability to demonstrate implicit and or explicit analysis of constituent groups of sounds (syllables and rimes) and single sounds (phonemes).

At first glance the difference in predictors of reading between deaf and hearing children suggests that deaf children's reading is **qualitatively** different to hearing children. It makes intuitive sense that hearing impairment will impact on the ability to develop awareness of speech sounds. If deaf children are unable to develop phonological awareness then the mechanism for decoding print (i.e. mapping graphemes on a page to stored words, 'lexemes' in the brain) is likely to be very different to that used by hearing children. In the presence of an auditory perceptual deficit the assumption is that deaf children will rely on input received through the visual and tactile modalities to a greater extent than their hearing counterparts (see Spencer, Erting & Marschark, 2000). So, rather than decoding written words into sounds and accessing the lexeme via a phonological process as seems to be the case for hearing children, deaf children might rely on visual characteristics of the printed word to access lexemes. In the early stages of reading, it seems that hearing children use a whole word recognition or 'logographic' strategy, however, this is common only in the very early stages of reading in hearing children (Frith, 1985). Ehri (1992) has shown even in the early stages of reading hearing children can make connections between graphemes and phonemes and that this sensitivity supports early word reading. All theories of reading propose that learning to associate graphemes with speech sounds is critical in learning to read an alphabetic script. Some hearing children who have difficulties with phonological approach to reading can rely heavily on contextual cues in the text to read/recognize new or difficult words (Nation & Snowling, 1998). In fact, Nation and Snowling argue that this 'semantic bootstrapping' strategy is the mechanism whereby many dyslexic children eventually achieve reasonable levels of word reading accuracy despite their continuing deficits with phonological awareness. It is feasible therefore, that deaf children could also rely on semantic and contextual strategies in a similar way to dyslexic children. This would explain the reason for the strong relationship between vocabulary knowledge and reading. There are several studies which show that good deaf readers are able to derive word meanings using context strategies when reading (de Villiers & Pomerantz, 1992, Paul, 1998). These findings strongly indicate that the wider language and vocabulary deficits commonly found in deaf children restricts the efficiency of a semantic back-up strategy, thus accounting for the historic and pervasive reading deficits of the majority of deaf children.

The primary aim of cochlear implant fitting is to attenuate the delay in spoken language acquisition. If it is successful in doing this, and if vocabulary development is predictive of reading outcome in deaf children because they rely on context strategies to read then we should expect higher reading attainment for those children who use cochlear implants. However, there is also some evidence from the literature that vocabulary knowledge might not be the only determinant of reading for deaf children. Originating with the work of Conrad (1979) and Dodd (1976) we know that profound deafness does not always preclude the development of a phonological system. In fact, there is some evidence to show that phonological awareness is associated with reading attainment in deaf children (see Chapter 2). If, as intended, the fitting of a cochlear implant enhances auditory perception then this might make it easier for deaf children to develop phonological awareness. Therefore, the fitting of an implant might be expected to enhance reading attainment via two enhancements; increased vocabulary knowledge (which would support semantic strategies for reading) and increased phonological awareness (which would support phonological strategies for word decoding).

So far, vocabulary and phonological knowledge have been presented as if they were components each providing a separate and unique contribution to the reading task. In fact, in this thesis I want to argue for a more integrated view of these two linguistic developments in terms of their relative contribution to the reading abilities of deaf children. In this thesis, I take the position that linguistic representation (specifically phonological representation) and the structure of the representations emerges over time and out of language use. Phonological representations are not considered as stored perceptual events therefore, increased auditory perception derived through a cochlear implant is not viewed as the **sole** determiner of phonological awareness. Instead I will posit that the origin and developing structure of the phonological representations is intimately related to vocabulary acquisition. Cochlear implant fitting is predicted to aid vocabulary learning which in turn will shape the structure (in terms of the level of segmental organization) of the phonological representations. In this thesis the level of segmental organization is assessed by examining awareness of three phonological units; the syllable, the rime and the phoneme. The most rudimentary of these units is the syllable, rime and phoneme awareness represent progressive stages of segmental organization of the phonological lexicon. The degree of segmental organization of the underlying phonological representations will support phonological awareness which in turn might impact on reading ability. If vocabulary acquisition does drive segmental organization of the underlying phonological representations then vocabulary knowledge should be a determinant of phonological awareness.

As an introduction to the thesis I consider hearing **impairment** and explore the reasons why a cochlear implant is thought to be a better prosthetic device for the remediation of profound hearing impairment than a conventional hearing aid. If, as suggested, enhanced auditory perception is not the sole determinant of phonological awareness then this introductory chapter must also include a discussion of the origins of language disability in deaf children. Locke's (1997) Neurolinguistic Development Theory is used as a theoretical framework for this discussion because it provides a cohesive account of the way that early vocabulary acquisition might be causal in determining the structure of the phonological lexicon.

1.2 Hearing and Hearing Impairment

In order to understand how a cochlear implant works we first need to briefly consider the ear, how it works to enable speech to be perceived and the consequences of hearing impairment.

1.2.i Structure and Function of the Ear

The ear has three main components, the outer ear, the middle ear and the inner ear. All of these components are specialized to conduct and boost sound. An impairment of any of these structures or their function will result in a hearing impairment. However, we will limit our explanation to the inner ear because impairments in the inner ear cause sensorineural hearing loss.

The cochlea is a fluid filled snail-shaped cavity situated in the temporal bone of the skull. In the centre of the bony cavity is a membranous duct (cochlear duct). A membrane (basilar membrane) runs the entire length of the cochlear duct and the organ of hearing, the organ of Corti is situated on the basilar membrane. The organ of Corti contains 20,000 auditory receptor cells (hair cells). The hair cells are of two types, outer hair cells and inner hair cells.

Sound, in the form of mechanical pressure is transmitted to the cochlea through a connection at the base of the cochlea with the middle ear (oval window). The stapes (a small bone in the chain of ossicles in the middle ear that connects the middle ear to the inner ear) rocks on the oval window and the rocking causes pressure variations in the fluids of the cochlea which displaces the basilar membrane exciting the auditory receptors which leads to the firing of neurons in the cochlear nerve. Axons from the neurons in the cochlear nerve project to the brainstem, the auditory fibers synapse on interneurons in two auditory nuclei of the medulla. Axons from these nuclei cross in the brainstem and ascend to the thalamus from where pathways project to the auditory cortex in the temporal lobe.

Frequency and Intensity Coding

There are two components of a wave form, frequency and intensity. We need to briefly explore how the cochlea codes these properties. The basilar membrane varies in width and stiffness. At the base of the cochlea it is narrow and stiff and at the apex it is wide and flexible. The structure of the basilar membrane means that it has different resonating frequencies along its length. At the base, it has high resonating frequency and at the apex, lower resonating frequency. As the pressure wave is set up in the cochlea, the basilar membrane resonates to the frequency of the pressure wave at the place on the membrane that corresponds most closely to its own resonant frequency. So, the basilar membrane would vibrate at the base of the cochlea in response to a high frequency sound and at the apex in response to a low frequency sound. Thus, discriminating frequency of sounds is due to a **place coding** mechanism. The outer hair cells are thought to boost and attenuate vibrations of the basilar membrane, which further enhances frequency analysis. In addition, the tonotopic organization of the neurons in the cochlear nerve means that pure tones are represented in a sequence on the cortical surface. Neurons transmitting information about high frequency sounds are on the outside of the auditory nerve and the neurons transmitting information about low frequency sounds are more centrally located in the bundle and therefore less prone to damage. The tonotopic organization is also thought to aid frequency resolution. Changes in intensity cause a corresponding change to the degree to which the basilar membrane is displaced. The degree of displacement of the basilar membrane is coded by rate of firing and the number of firing neurons.

1.2.ii Sensorineural Hearing Impairment

There are many causes of sensorineural hearing impairment resulting in a range of pathologies to the cochlea. However, there is always damage to the hair cells and varying degrees of neuronal damage in the cochlear nerve. Sensorineural hearing losses are likely to be worse in the higher frequencies (Bamford & Saunders, 1991). This may be due to the fact that high frequencies resonate at the basal end of the cochlear, which, due to its proximity to the middle ear is more prone to damage. Alternatively, the positioning of the neurons carrying information about high frequency sounds, which are on the outside of the bundle of the cochlear nerve, could cause them to be more vulnerable to damage. Whatever the reason for the higher frequency loss, it turns out that a large proportion of acoustic cues for speech perception are carried in the higher frequencies.

1.2.iii Speech Perception

In order to understand why a cochlear implant is considered a better prosthetic device for the remediation of hearing impairment we need to briefly consider how speech is perceived.

The cues we use to perceive speech relate to the timing of events (temporal cues) and the frequency of those events (spectral). Speech sounds are complex, meaning that they all contain more than one characteristic frequency. The acoustic cues we use to perceive speech may be degraded in the presence of competing noise, or change with different speakers and varying rates of speech. Perception of speech sounds made with an open vocal tract (i.e. vowels and semi-vowels) is easier than those made with a closed or tightly constricted vocal tract (i.e. consonants). This is because sounds made with an open vocal tract are louder, they last longer and they generally have lower characteristic frequencies than consonants.

Vowels

The acoustic cues for vowel perception are energy bands at different frequencies (formants). Vowels have several formants at different frequencies and the general pattern of formant frequency (not the actual frequency of each formant) is the acoustic cue we use to discriminate vowels. The formants of vowels are relatively low in frequency compared to other speech sounds. For example the vowel /ee/ as in 'tree' has an energy band at a low frequency (300 Hz), a second band at a much higher frequency (2500 Hz) and a third band just above the second (3000 Hz). In contrast, the vowel /ah/ as in 'car' has a higher first formant (800 Hz), a lower second formant (1000 Hz) with the third formant being around 2500 Hz. So, for the vowel /ee/, the basilar membrane would vibrate at three points along its length according to the frequencies of the three formants of the vowel. The greatest amount of displacement of the basilar membrane would take place at 300 Hz because the lower frequency speech sounds are loudest in intensity. However, /ee/ has the highest frequency formants of all the vowels, making it the most difficult vowel for a profoundly deaf person to perceive.

Consonants

The basic categorization of consonants is according to three facets of production, voice, place and manner. **Voice** describes whether the vocal folds vibrate during production (i.e. voiced sounds – where the vocal folds vibrate and voiceless sounds – where the vocal folds do not vibrate). **Place** relates to the position in the oral cavity where the constriction is made (i.e. labial – with constriction at the lips, alveolar – with a constriction behind the top front teeth, palatal – with a constriction at the palate and velar where the constriction is at the back of the oral cavity near the velum. **Manner** relates to the way in which the sounds are produced. Nasals are made with air released through the nasal rather than the oral cavity, fricatives are produced by making a tight constriction through which air passes with turbulence, affricates are similar to fricatives except the air flow is preceded by a total constriction in the oral cavity and stops are produced with a complete obstruction of the oral cavity.

Perception of Stop Consonants

The stop consonants /p, b, t, d, k, g/ are the least 'vowel like' of all speech sounds. The acoustic cues used for stop perception are overlaid upon the acoustic cues of the neighbouring vowels. The most salient acoustic cue relating to the voicing of a stop is the relative delay in the start of the formant for the following vowel (vowel formants start earlier for voiced sounds than for voiceless sounds). Voicing cues are derived from the timing of an event (temporal cues). A salient acoustic cue for identification of the place of articulation is the change in frequency of the formant as it goes into the vowel. Place cues are derived from frequency information (spectral cues). Acoustic cues to the manner of articulation for stops are, the presence of silence (as the occlusion is held), a burst in energy as the stop is released and the relatively rapid formant transition into the vowel. Acoustic cues to the manner of articulation for stops are a mixture of temporal and spectral cues.

Summary

Under normal listening conditions hearing provides all the information necessary for the perception of speech. In the presence of sensorineural hearing impairment, the most difficult articulatory feature to perceive is that of place of articulation since the cues are all carried in the frequency of the sound.

1.2.iv Visual Speech Perception

In noisy listening conditions, perception of the place of articulation is eroded, but information about the voicing and manner of articulation tends to be preserved (see Borden & Harris, 1984). The weakness in the auditory system, under ambiguous listening conditions, to resolve cues about place of articulation, is complemented by information derived through the visual system (i.e. through lipreading) (Summerfield, 1987). Information on the place of articulation is perceptually salient through the visual modality. However, many aspects of speech, both segmental (vowels and consonants) and supra-segmental (stress and intonation) are invisible. Hearing people, untrained in lipreading are able to accurately identify forty percent of phonemes in syllables using lipreading alone (Montgomery, Walden, & Prosek 1987).

When researchers wish to simulate the effects of sensorineural hearing loss they use a low-pass filter, which filters out high frequency sounds, and they add noise to the system. Such an experiment was carried out by Blamey and Clark (1988). They showed that under conditions that simulated sensorineural hearing impairment, hearing people find it difficult to perceive the place of articulation using hearing alone (scoring 24% accurate). With visual information alone, place of articulation was 100% accurate. The complimentarity of the visual and auditory systems means that lipreading combined with residual hearing can enable speech perception of vowels and consonants even in the case of profound deafness (Boothroyd, 1993). However, this is not always achievable by profoundly deaf people. In order to understand why some deaf people are able to achieve speech perception and others are not we need to consider the possible contributory factors.

The summary of speech perception provided here is necessarily brief. The use of the terms vowels and consonants may lead to a false impression that there is a one-to-one mapping between an articulatory or acoustic event and a phoneme. In English /p/ and /b/ are separate phonemes (i.e. the smallest unit of sound which when changed signals a change of meaning). Adding /p/ or /b/ to the vowel 'ee' (i.e. 'pea' and 'bee') results in two different lexemes being activated. The study of acoustic and articulatory phonetics shows that one phoneme can have many articulatory and acoustic realizations (referred to as the phoneme's allophones). Allophonic variation can be dependent on context, speaker and linguistic factors such as the position of the sound in the syllable and the features of the neighbouring sounds. For instance, the phoneme /t/ in the word 'Gatwick' is likely to be produced by closure at the vocal folds (i.e. in the larynx, referred to as a glottal stop by phoneticians). The /t/ in the word 'tap' will be produced by closure of the tongue against the alveolar ridge (just behind the top front teeth) and will be released with an audible puff of air (aspiration) which can be recorded acoustically. The glottal stop (in the word 'Gatwick') is not released with audible aspiration. Knowing what groups of sounds (allophones) constitute a single phoneme develops over time. We will go on to consider the determinants of phoneme awareness later in this chapter, but we will see that there is no simple causal relationship between auditory perception and phoneme awareness.

1.2.v Degree of Hearing Impairment

The most commonly used measurement of hearing is the pure tone audiogram. This is a behavioural test. Pure tones are presented through headphones at a range of frequencies and loudness levels. The testee responds when he or she hears a tone. Both ears are tested separately. The responses are plotted on a graph with frequency across the y axis and loudness level down the x axis (see figure 1.1). The loudness level starts at 0 db HL which is the volume at which people with normal hearing can just detect a pure tone. It extends to 120 db HL which represents the volume at which sounds can be felt as vibrations in the body. Testing sound awareness above this loudness level will be confounded by vibro-tactile perception. Degree of hearing impairment is calculated based on the loudness level at which a response is made to frequencies at which cues for speech perception of vowels and consonants are present. In the UK the frequencies included in the calculation are 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz (as used by Davis in the National Study of Hearing conducted by the MRC, Davis et al, 1995). However, the lower frequency of 250 Hz can also be included. Typically, the average of the responses from four frequencies is taken and the result is based on the responses from the better ear (Beagley & Barnard, 1982). In the UK, degree of hearing impairment is classified as either; mild (average response in the range of 20 – 40 dB HL), moderate (41 – 70 dB HL), severe (71 – 95 dB HL), profound (> 95 db HL). So, a person with an average response in the better ear to pure tones at 500Hz, 1kHz, 2kHz and 4kHz of 85dB HL would be categorised as having a severe hearing loss and an average response of 102 db HL would be categorised as profound. In some rare cases hearing loss is total (i.e. no response to a pure tone at any frequency presented at 120 dB HL).

The formula for calculating the average pure tone threshold and the cut off thresholds used for defining categories of hearing impairment is different in the USA and Australia. In the USA and Australia profound deafness is defined as being above 90 db HL (ANSI, 1989) and pure tone averages are calculated from **three** frequencies (500 Hz, 1000 Hz and 2000 Hz). The higher frequency (i.e. 4000 Hz) is not included. The differences in the calculation of degree of hearing loss can be significant because it can lead to a difference in the classification of the hearing impairment. Let us consider a hypothetical case where the responses to pure tones in the better ear are;

80 dB HL at 500 Hz,
90 dB HL at 1000 Hz,
100 dB HL at 2000 Hz.

The hearing loss (average 90 dB HL based on these three frequencies alone) would be described as profound in the USA, but severe in the UK. Now, let us consider the difference between the two calculation methods in terms of the omission (USA) or inclusion (UK) of the fourth frequency (i.e. at 4000 Hz). Given the anatomical structure and physiological mechanisms of the inner ear and central pathways it is more common for hearing impairment to be greater in the higher frequencies (i.e. due to the vulnerable position of the fibres transmitting high frequency sounds in the auditory nerve, exposure to damage of the narrow apex in the cochlear where the basilar membrane resonates to high frequency sounds). Take a case where the response to pure tones in the better ear is the following;

70 dB HL at 500 Hz,
85 dB HL at 1000 Hz,
105 dB HL at 2000 Hz
120 dB HL at 4000 Hz.

In the USA this loss would be described as severe (86.6 dB HL) but in the UK the loss would be described as profound because the fourth high frequency response is included in the calculation (95 dB HL).

The differences between the two methodologies (i.e. classification cut-off frequencies for profound deafness and inclusion or omission of the response at 4000 Hz) can lead to different classifications of degree of hearing loss given the same set of responses. Therefore, what constitutes 'severely deaf' in one continent and study might be 'profoundly deaf' in another. Perhaps because of these differences in classification hearing impairments around 90 to 95 dB HL are now often referred to as 'severe-to-profound'. The examples above show that the differences between the two methodologies cannot be resolved by the application of a simple metric to transform the data to eradicate the difference. However, we must be aware that these differences exist especially when seeking to analyse and synthesise research findings from different continents.[1]

Whilst the pure tone audiometric result is the most common way of classifying degree of hearing impairment, factors such as the shape of the hearing impairment (in terms of the threshold to different frequencies) can be more important in determining degree of auditory perception and resolution in sensorineural hearing loss (Bamford & Saunders, 1991). In order to understand more about the functional auditory perception in sensorineural hearing loss we consider Boothroyd's (1993) definition and classification of auditory capacity.

Auditory Capacity

Auditory capacity, defined by Boothroyd (1993), is the ability to detect and differentiate sound patterns. Hearing loss measured by the pure tone audiogram is an important component of auditory capacity, but not the only one. The ability to detect and differentiate sound patterns is also dependent on dynamic range and auditory resolution.

Dynamic range is the difference between the loudness level at which a sound can be detected (audibility threshold) and the loudness level at which sounds are so loud that they are uncomfortable to listen to (discomfort level). In hearing people the audibility threshold is at 10 dB HL and the discomfort level at 100 dB HL, giving a dynamic range of around 90 dB HL. The dynamic range is reduced in profoundly deaf people, seldom exceeding 30 dB HL (Boothroyd, 1993). Furthermore, it varies with frequency. Dynamic range may be narrower in the high frequencies relative to the low frequencies. This reduction in dynamic range offers a major challenge in amplifying sound using conventional hearing aids. Specifically, reduced dynamic range in the high frequencies

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[1] In this thesis the UK methodology is used for calculating pure tone thresholds. So, the groups of deaf children in the study are classified as either severely hearing impaired (pure tone thresholds in the range of 71 to 95 dB HL, with averaged response from 4 frequencies, 500 Hz, 1kHz, 2kHz, 4kHz) or profoundly hearing impaired (pure tone thresholds above 95 dB HL).

means that amplification of sounds in high frequencies may not be possible using conventional hearing aids.

Auditory resolution is the ability of the neural system to derive patterns from spectral and temporal acoustic cues. Profoundly deaf people with the same degree of residual hearing can have markedly different auditory resolution. Some profoundly deaf people are able to use residual hearing with hearing aids to understand speech over the telephone. This is a particularly challenging task because of the limited range of frequencies transmitted, the distortion of sound and the absence of lip cues to support speech perception. Other profoundly deaf people are able to resolve fairly gross variations in intensity. This allows them to detect environmental sounds and the rhythm of speech, but does not support speech perception of vowels and consonants (Boothroyd, 1993).

The combination of the degree of hearing impairment, dynamic range and auditory resolution together with listening experience result in auditory capacity. Boothroyd (1993) defines four categories of profound deafness in terms of auditory capacity.

	PTA	**Dynamic Range**	**Auditory Resolution**
Category Auditory Capacity			
Considerable	90 dB HL	30 dB HL	vowels and most consonants
Moderate	100 dB HL	20 dB HL	vowels and 25% of consonants
Minimal	110 dB HL	10 dB HL	rhythm & intonation only
None	120 dB	0 dB HL	None

It is clear that there is a strong association between degree of residual hearing, dynamic range and auditory resolution. Using pure tone audiograms in isolation will not be sufficient to predict auditory capacity.

Hearing Aids and Auditory Capacity

Auditory capacity is also dependent on the degree of amplification derived through a hearing aid. A hearing aid works by amplifying sounds so that they are loud enough to be detected with residual hearing. The gain that can be afforded with a conventional hearing aid is moderated by dynamic range which is in turn related to the degree of residual hearing. Typically, sensorineural hearing loss results in greater hearing impairment of high frequencies. This, combined with technical limitations of conventional analogue hearing aids means that information about high frequency sounds where the vast majority of cues that seem to be essential for the discrimination of vowels and consonants is difficult to deliver using conventional hearing aids.

1.2.vi Components of a Cochlear Implant

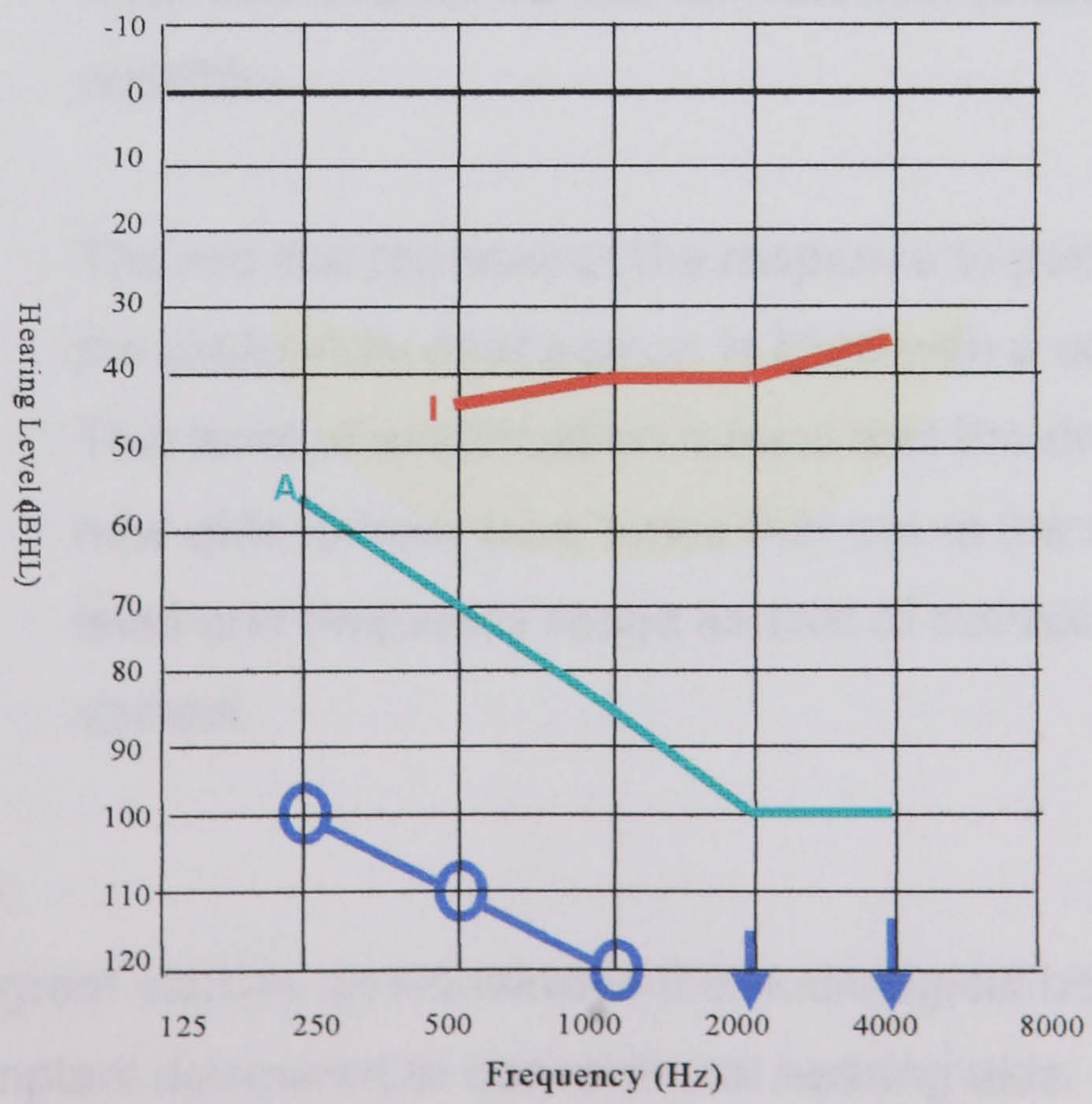
A cochlear implant works by directly stimulating the cochlear nerve. The range of frequencies presented to the cochlear nerve is broader than that which can typically be achieved with a hearing aid because it is not limited by residual hearing and dynamic range. In theory, therefore, a range of frequencies of equal loudness levels can be presented to the auditory nerve via electrical stimulation.

The five main components of a cochlear implant are; a microphone, a speech processor, an encoder, a decoder and an electrode array. The microphone, speech processor and encoder are external components and the decoder and electrode array are the internal components. The microphone is worn behind the ear fitted in a case that looks like a conventional hearing aid. A lead connects the microphone to the speech processor. The speech processor is either worn on the body, resembling a small personal radio, or behind the ear in the same case as the microphone. During surgery a hollow about the diameter of a 2 pence piece is made in the temporal bone of the skull. The decoder or implant receiver is situated in this recess. The electrode array is inserted into the cochlea so that the electrodes are situated close to the auditory neuron terminations in the Organ of Corti.

The microphone senses sounds in the environment and converts the pressure variations into electrical variations. The electrical signal is processed by the speech processor which is then encoded for transmission to the decoder using radio-frequency. The transmission takes place through a transcutaneous link. A small coil on the outside is magnetically attached to the internal cochlear implant receiver. The signal is decoded and the electrodes are stimulated. Electrical impulses are transmitted to electrodes in frequency bands. High frequencies are transmitted to the electrodes nearer the base of the basilar membrane and lower frequencies are transmitted nearer to the apex.

The following stylized audiogram demonstrates the audiological benefits of a cochlear implant compared to conventional hearing aids for a profoundly deaf person with a hearing loss (figure 1.1).

figure 1.1 Pure Tone Audiogram



Key

The yellow banana shape in the centre of the audiogram represents the range of frequencies and loudness level at which conversational speech takes place.

The blue line represents the unaided responses made to pure tones by a profoundly deaf person. A person with this degree of hearing loss would be considered a candidate for a cochlear implant. The downward arrows show that no response to pure tones was made to sounds at 2000 and 4000 Hz when presented at 120 dB (HL).

The green line represents the response to sounds when the profoundly deaf person is wearing conventional hearing aids. With hearing aids the deaf person is able respond to a range of pure tones at lower loundness levels, however, access to pure tones that are at the same frequency and loudness level as normal conversational speech is not possible.

The red line represents the response to pure tones when the profoundly deaf person is fitted with a cochlear implant. This level of amplification means that the deaf person is now able to hear pure tones that are at the same loudness level and frequency range as that of normal conversational speech.

Summary

This audiogram visually demonstrates the audiological benefits of a cochlear implant compared to conventional hearing aids. The fitting of a cochlear implant allows the perception of sound across the full frequency range in which acoustic cues of all the consonants and vowels occur.

However, its fitting does not restore normal hearing. In fact, Boothroyd (1993) predicted that the average paediatric cochlear implant user is able to achieve the same auditory capacity as a profoundly deaf child using conventional hearing aids with an average pure tone threshold of 100 dB (HL). According to his definition of auditory capacity this means that children with implants would have moderate auditory capacity being able to perceive most vowels and about 25% of consonants. More recent studies show that the auditory capacity of paediatric CI users has improved slightly, perhaps by about 5 db (HL) (Svirsky & Meyer 1999; Nakisa, Summerfield, Nakisa, McCormick, Archbold, Gibbin & O'Donoghue, 2001). However, the confidence intervals of the means in the more recent studies still include the mean figure predicted by Boothroyd in 1993. Therefore, rather than reflecting change in auditory capacity across the board this improvement may be due to a sub-group (who may or may not become the majority group in the future) of children with implants who achieve the same auditory capacity as severely deaf children (i.e. 71 – 94 dB HL in the UK).

The ability to perceive speech is of course central in the development of spoken language. Cochlear implant fitting does enable very profoundly deaf children to have greater access to sound than is possible using conventional hearing aids. Improvement in auditory capacity through the fitting of a cochlear implant is expected to impact on the degree to which spoken language develops. However, functional outcomes in language and educational attainment will not be solely determined by auditory perception alone. Other factors such as the age of onset of profound deafness, the cause of hearing impairment and the age at which a cochlear implant is fitted (see Summerfield & Marshall, 1995) will contribute to outcome. There is some evidence that communication mode (i.e. aural/oral or manual signing), together with the degree of commitment on the part of the family to develop auditory skills will also affect outcome post implant fitting (Summerfield & Marshall, 1995). These factors will be considered in Chapter 3. To understand the reasons for the language and literacy disabilities associated with deafness we must look beyond the hearing impairment and consider the consequences of the impairment on other aspects of the deaf child's development.

1.3 Deafness and Disability

Before we can consider the issue of disability in relation to deafness the notion of typical and atypical must be explored. Applying the notions of typical and atypical or normal and abnormal to deaf children is particularly problematic. There is an important distinction between deaf children who are born to deaf parents and deaf children born to hearing parents. Deafness seems to result in less communication and language disability when deaf children are raised by deaf parents who are native sign language users (Marschark, 1993b). This is partly due to the modality of the language (manual signs are easier to perceive than spoken words for a deaf child) which means that receptive and expressive language development can take place within the normal developmental timescale (Newport & Meier, 1985). In addition, deaf parents are able to tune in to their deaf child more effectively than hearing parents. Deaf mothers are less directive and intrusive during interactions with their children than hearing mothers (Meadow-Orlans, 1990), their comments and behaviour are more likely to be contingent on the child's focus of attention than hearing mothers (Spencer & Gutfreund, 1990). Coutin and Melot (1998) show that communication mode predicts communication quality (signing is preferable to oral communication) and communication quality and parental tuning are predictors of theory of mind. So, deaf children of deaf parents are more likely to develop understanding of intentions, desires and beliefs enabling them to explain and predict human behaviour. Thus, deaf children of deaf parents have an advantage in terms of psychosocial development over deaf children born to hearing parents. The advantages in psychosocial and language development might be related to reading outcome. There is an indication that deaf children of deaf parents attain better reading and academic skills than those born to hearing parents

(Marschark & Harris; 1996; Braden, 1987). Deaf children of deaf parents are 'typical or normal' despite their hearing impairment.

Over ninety percent of deaf children are born to hearing parents. In a large sociological study of 122 young deaf children and their hearing families Gregory (1995) found that deafness had a major impact on all areas of daily life, both for the child and the family. Seventy percent of hearing parents said that their biggest problem in coping with a deaf child was due to communication difficulties. An even higher proportion of parents (89%) cited communication difficulties as being the major problem from the child's point of view. This work was originally published in 1976, however in the preface of the recent edition Gregory says,

"Despite significant changes in society since the early 1970s, including developments in attitudes to deafness and the legislation that affects deaf children and adults, many of the issues and concerns ..... are as crucial now in the 1990s as they were then." (preface pg. xiiii)

Therefore, we can expect that communication is still the main difficulty facing deaf children and their families. Gregory's book contains the transcribed interviews from carers, usually mothers. One thing that is striking from the extracts, pertinent to this discussion is that the level of disability encountered by the family is not directly related to the level of hearing impairment in the child. The following is a complete extract from an interview with the parent of a **moderately** deaf child,

"It's getting through to them when they're deaf. That's only snag, isn't it? Well you see if you've got a lad what's blind he can read Braille, they can be taught Braille and one thing and another. A lad that's disabled he can be taught to use his hands, but when they're deaf ..... " (page 181)

The sense of despair relating to communication is conveyed most powerfully by the unfinished final phrase. This extract suggests that disability caused by deafness is not necessarily related in a linear way to impairment. It also highlights the communication difficulties that deafness poses when a deaf child is born to hearing parents. This communication challenge was felt by all the families and not restricted to those where the child was severely or profoundly deaf. Perhaps deaf children born to hearing parents could be described as atypical compared to their typically developing deaf peers who are born to deaf parents.

It seems that ease of communication and quality of communication may be causally related to disabilities of communication, language and literacy.

1.4 Phonological Development and Literacy

In order to advance the theoretical position of this thesis the evidence for an emergent theory of phonological knowledge is required. Auditory perception is not considered to be the sole determiner of linguistic (i.e. phonological) representation, but, in line with current phonological theories I argue that the expanding lexicon is responsible for emergent phonological ability. In order to develop this argument I will consider how experience (specifically vocabulary expansion and the timing of the vocabulary burst) affects the structure of the phonological representations using Locke's Neurolinguistic Development Theory (1997). The final part of this section concludes with a summary of why the structure of the phonological representations is related to literacy development in the hearing child and consider the relevance of this model to the deaf child.

1.4.i The Development of Phonological Representations

Infants possess remarkable abilities at discriminating phonetic differences between speech sounds (Eimas, Sequelend, Juscyk & Vigorito, 1971). These findings were seen as congruent with the pervading phonological theory of the time (i.e. Chomsky & Halle, 1968) where the phoneme was considered to be the unit of phonological representation from the outset of language learning. Early accounts of the nature of phonological representations suggested that perception was equal to representation. According to this view every phoneme that could be discriminated was represented or stored as part of an abstract representation in the brain. Therefore, since young infants are capable of discriminating virtually all phonemes the phoneme was considered to be the structural unit of the speech representations. However, knowledge of the nature of the underlying phonological representations has since changed. Based on a review of behavioural evidence from speech perception and speech production research, Fowler (1991) suggested that lexical representations become increasingly segmental between the ages of one and eight years. She showed that early in development phonetic features are spread across the whole lexical representation and it is only with increasing age that children become more attentive to (when discriminating) or influenced by (when speaking) the single phonetic event. Fowler's proposal is that phonological representations are initially represented holistically, becoming increasingly segmentally organised over time. Recent anatomical evidence supports Fowler's proposal. Moore and Guan (2001) examined the maturation of auditory cortex using postmortem tissue from subjects ranging in age from the 16th fetal week to 20 years of age. They found anatomical evidence to show that the early discrimination abilities of infants (i.e. under 6 months of age) could not be due to cortical processing since there are no mature axons extending from the thalamus to the cortex prior to 6 months of age. They conclude that phonetic discrimination in infants is due to processing at the brainstem rather than cortical level. Therefore, evidence of phonetic discrimination does not equal evidence of phonemic representation.

According to Lindblom and his colleagues (Lindblom, MacNeilage, Studdert-Kennedy, 1984) phonological structure emerges a result of the repeated exposure to the properties of the substance (i.e. the phonetic properties of the words in the language). If this position is correct, then we should expect to find properties of the **input** reflected in the underlying structure. There is an increasing body of research that suggests that this is the case. For example, words that are highly frequent in the language have stronger representations in the sense that they are more easily accessed and low frequency words are more difficult to access (Katz, 1986). Bybee (2001) asked subjects to make judgements about the permissibility of a new word. She found that subjects based their judgements on the phonotactic statistics derived from the frequency of occurring sound sequences in the language that they knew rather than on rules about permissible syllable structure. Bybee (2001) claims that phonological theories based on categorical feature and phoneme constraints cannot predict these kinds of frequency effects. In accordance with the view that phonological representation changes over time and that the mechanism of change is language use, Metsala and Walley (Walley, 1993; Metsala & Walley, 1998) suggest that vocabulary development is the key determinant of a segmentally organised lexicon. They state that when vocabulary size is small utterances can be stored as whole units, however, this type of storage is limited. As the volume of items increases, holistic representations gradually become restructured so that eventually, the phoneme emerges as a representational unit. The relationship between the vocabulary burst and phonological development has also been reported in studies that have investigated speech output. Roberts (1999) showed that the number of phonological contrasts produced significantly increased after the vocabulary burst. The actual sounds used to signal the contrasts were present in the child's articulatory inventory prior to the vocabulary burst, but the phonological organization of those articulatory gestures was more mature following the rapid acquisition of words.

Taken together such evidence suggests that phonological organization emerges over time. The alternative position would be that children begin phonological acquisition form the very onset of word learning. In this theory the child starts off with an underlying phonological template the properties of which are the same as that found in the adult phonological system (Ingram, 1999). The theoretical bias of this thesis is towards an emergent rather than an innate proposal of phonological development.

1.4.ii The Development of Phonological Awareness

Hearing children's awareness of sounds in words and their ability to manipulate sounds in words follows a developmental pattern that seems to support the view that phonological representations become increasingly segmentally organized over time. Liberman Shankweiler, Fischer and Carter (1974) used a tapping task to test children's developing awareness of syllables and phonemes. They found that it was easier for children to tap out the three syllables in a word like 'butterfly' than to tap out the three phonemes in a word like 'b-u-t'. Nearly half of the children aged four years were able to correctly tap out syllables, in contrast, none of the children at this age were able to correctly tap out phonemes. Trieman and Zukowski (1991) examined a third linguistic level of intra-syllabic awareness at the onset/rime level in a similar study of syllable and phoneme awareness. Their results indicated a developmental progression of speech sound awareness. Recognising shared syllable segments was the easiest level, followed by awareness of shared onset/rime segments and awareness of shared single phonemes was the hardest level. Trieman and Zukowski (1991) also showed that recognising the rime, which occurs at the end of the word was easier than detecting shared onsets (at the beginning). However, the reverse pattern was true when detecting single sounds. Detecting shared phonemes at the end of a word was much harder than detecting shared phonemes when they occurred at the beginning of words. Research converges from differing methodologies to support the view that phoneme awareness is reciprocally related to reading development (Lundberg, 1991b; Wimmer, Landerl, Linortner & Hummer 1991; Morias, 1991). Although phoneme awareness can be observed in pre-schoolers (Kirtly, Bryant, MacLean & Bradley, 1989), this is largely dependent on the phoneme being the onset of a word.

So far there is evidence to show that the structure of phonological representations changes over time becoming increasingly segmentally organised during childhood and that input affects the structure of the underlying representation. The modality of the input appears to be somewhat irrelevant in that both auditory and visual input can impact on the structuring of the phonological representation. Language learning (i.e. via the auditory modality) impacts on the structuring of the phonological representation and interaction with print (i.e. via the visual modality) is at least reciprocally related to the development of phonemic representation. So, whilst we have described the change in structure and the interactions with language that bring about change we have not described a **mechanism** responsible for this change. We now go on to examine Locke's proposition that vocabulary acquisition is a crucial determinant of linguistic competence (which includes the development of phonology) because it is responsible for the instantiation of an innate biological mechanism which is responsible for the identification of recurring patterns in the input.

1.5 Locke's Neurolinguistic Development Theory

In Locke's theory grammatical ability is considered to be an emergent property of an expanding lexicon. He is not alone in his lexicalist, non-modular perspective of language development. Bates and her colleagues have also argued for a similar position in terms of the inseparability of grammar and the lexicon (Bates & Goodman, 2001). Using early language acquisition data from normal and atypical groups Bates argues that grammar and the lexicon develop together in infancy and also breakdown together in brain-injured adults. According to Bates this inseparability is due to having,

"one neural architecture in which grammar and the lexicon are represented together, and handled by the same mechanisms for learning and processing". pp 158 (Bates & Goodman, 2001)

According to Bates, evidence from children with developmental learning disorders shows that grammatical development takes place once the vocabulary burst happens (regardless of the age of the child). Locke claims that the degree of grammatical representation will be affected by the **timing** of the vocabulary burst. This lexically lead perspective of the development of grammar is not universally accepted. Pinker (1991) would argue for a more dissociated view of lexical and grammatical competence, claiming that these aspects of language are served by separate and specific mechanisms.

The case of language development in children with Williams Syndrome (WS) has often been used as evidence in support of a modular perspective on language ability. Children with Williams Syndrome is a genetic syndrome resulting in mental retardation. The mean IQ is typically in the range of 40 to 60 but, unlike children with Down's Syndrome, who have a similar level of mental retardation, speech is fluent and grammatically correct. Based on surface level analysis of these children's expressive grammar it was claimed that the mechanisms that serve linguistic development are dissociated from mechanisms that support general learning (i.e. Pinker, 1991). Such evidence would appear to contradict Locke's theory because WS children are delayed in their acquisition of vocabulary (Bates and Goodman, 2001). However, more recent studies (Karmiloff-Smith, Tyler, Voice, Sims, Udwin, Howlins & Davies, 1998) have found that some aspects of syntactic processing are impaired in WS. It is possible then that a surface level analysis of English speaking WS subjects is not sufficient to identify subtle under-specified grammatical representation. Karmiloff-Smith (2001) has argued elsewhere that the extrapolation of conceptualisations about modularity of language derived from children with developmental disorders might lead to misleading conclusions. According to Karmiloff-Smith, different behavioral outcomes observed in children with developmental disorders could stem from very small changes in the initial state (such as the rate of firing of neurons) rather than being caused by the absence of an innate module. She also warns that the developmental course of children with learning disorders could be different to that of 'typical development'. In line with Karmiloff-Smith's neuroconstructivist philosophy, Locke attempts to seek a cause for language disability by considering early non-language specific changes that might effect of the eventual development of language competence.

1.5.i Phases and Mechanisms of Locke's Theory

Locke describes four linguistic phases each of which are supported by a neurocognitive mechanism. He posits that each of these mechanisms has a biologically optimal time (critical period) during which the linguistic function dependent on the associated neurocognitive mechanism can take place. Additionally, the linguistic development achieved in each phase supports the development of subsequent linguistic phases. A summary of the four phases is provided (table 1.1).

table 1.1 Summary of Neurolinguistic Development Theory (Locke, 1997)

Phase 1 - Social Cognition and Communication

Locke shows how early socially cognitive mechanisms, such as infant's orientation to faces and voices, support socially cognitive operations such as vocal turn taking, imitation of prosody and communicative gesturing. *"The infant's socially cognitive operations therefore contribute to the first few essential phases in the development of linguistic capacity"* (page 269).

Clearly, profound hearing impairment will impact on the deaf child's ability to orientate to voices. However, a deaf child may engage in non-auditory cognitive operations, for example manual babbling (Orlansky & Bonvillian, 1985). When a deaf infant's manual babbling is reciprocated, their sign language skills are enhanced (Meier & Newport, 1990). Therefore, the key sociolinguistic function of this stage is not necessarily precluded by hearing impairment. There is some evidence from Yoshinaga-Itano and her colleagues (Yoshinaga-Itano, Sedey, Coulter & Mehl, 1998) that diagnosis of deafness before the age of 6 months can significantly reduce the gap between cognitive ability and language ability in deaf children. The difference in language quotients between children diagnosed early and those diagnosed after 6 months of age was not related to **degree** of hearing impairment. All children diagnosed early, regardless of the degree of hearing impairment, had higher language quotients than comparable children diagnosed later. This research may have implications on the optimum period suggested by Locke, as these findings suggest that it is narrower than 12 months.

In the UK, despite new technology that permits accurate screening of hearing in neonates, deafness is not typically diagnosed until the age of 8 months (Davis, Wood, Healy, Webb & Rowe, 1995). The fitting of hearing aids might take place within four weeks of a diagnosis (Gregory, 1995). Access to specialist advice on appropriate communication strategies is likely to be more significantly delayed if it is available at all (Baguley, 1999). Therefore, the socially cognitive operations of the vast majority of deaf infants may be unrecognised and unreciprocated by their hearing caregivers for the entire optimum period of Locke's proposed first phase. Even if hearing aids are successfully fitted within the first year of life, limited communicative reciprocity (between a deaf child and his or her hearing parent) is likely to have implications on the ability of the child to collect and store utterances.

Phase 2 - Utterance Acquisition

The acquisition of learned phrases and single words is initially highly dependent on the context in which the phrase or word is used. Children learn to associate phrases with specific events, e.g. "time for bed". It is thought that this process is facilitated by caregivers who repeatedly use the same phrase with the same intonation and stress pattern to signal an event. The child is unaware of the constituent elements of these phrases (i.e. morphemes and phonemes) even though they are recognized and produced by the child. Locke describes these utterances as "starter utterances". Their main function is to support social interaction. The lack of segmental specificity of these utterances means that there is an upper limit on the number of utterances that can be stored (Lindblom, 1989). According to Locke, the rapid acquisition of language or vocabulary burst (Benedict, 1979) which takes place at some point before the end of the second year, is responsible for the inception of the third phase of analysis and computation.

Phase 3 - Analysis and Computation

Crucially, it is the child's stored utterances that provide the required stimulation to activate the analytical mechanism. If utterance acquisition is **delayed** or **lacking in volume** at the time when the analytic and computational mechanism is optimally poised to operate, the resulting linguistic system will be characterised by an inability to derive phonological, morphological and syntactic rules. Clearly, this would have far reaching implications for the development of literacy skills. Locke draws on evidence from research with specific language impaired children to show that despite the fact that children may appear to catch up, exhibiting '**overt speaking behaviours**', lexically delayed children face long-term problems in the development of literacy skills. Some theories suggest that the phonological and linguistic deficits found in children with specific language impairment (SLI) are due to deficits in auditory processing of rapid temporal events (i.e. formant transitions) (Tallal, 1976; Tallal & Piercy, 1973). Although such theories appear plausible, more recent studies have failed to replicate Tallal's findings (Bishop, Carlyon, Deeks & Bishop, 1999) which suggests that auditory temporal processing deficits cannot fully account for the pervasive linguistic deficits found in children with SLI. In fact, a body of evidence showing that children with SLI are delayed in nonlinguistic tasks supports the 'maturational lag' hypothesis of SLI (Bishop & Edmundson, 1987b). Some of the associated delays (i.e. in gross motor development (Powell & Bishop, 1992) may eventually resolve to support functional motor skills. However, for Locke, the persistent language **disorder** is caused by an early **lexical delay**.

Summary

Lexical delay is at the heart of Locke's theory.

"When the lexically delayed finally have enough words, neurodevelomental conditions no longer favor instatement of grammatical capability. A child who has not realized a sizable lexical increase by about 24 months is therefore at developmental risk, for his analytical-computational capability may not turn all the way on. And even with subsequent advances, it could still be somewhat underdeveloped when the optimum activation period begins to subside." (page 288)

Locke's theory has some value as a framework to describe the chain of events that leads to communication, language and literacy difficulties in deaf children who are born to hearing parents. We know from work on sign language acquisition that delayed acquisition of language learning affects phonological and grammatical fluency in American Sign Language (Emmorey, 2002). Furthermore, work on second language acquisition tends to support the view that timing of input is important for ultimate fluency in language (Birdsong, 1999, but see Bialystok & Hakuta, 1999).

The reason Locke's theory is given a central position in this thesis is because of the way it can account for the relationship between vocabulary acquisition and phonology, hearing speech is not sufficient to develop well specified phonological representations.

One of the strengths of Locke's theory compared to other critical period theories of language development (i.e. Lenneberg, 1967) is the focus on social cognition as the foundation for language development. Perhaps the biggest weakness of the theory lies in the under-specificity of the relationship between the timing of lexical development (i.e. degree of delay) and predictions about ultimate linguistic competence. For example, it is not possible to say which skills or representations will develop if vocabulary acquisition is delayed.

A true test of Locke's theory must involve the collection of prospective longitudinal language acquisition data. Assessment of grammatical competence should be sensitive to the nature of the representation and resulting metalinguistic awareness rather than being based on surface level description. A description of the quality and quantity of language used is not likely to capture sufficient detail to test the theory. Children can exhibit 'overt speaking behaviours' but have underlying representations that are under-specified as seems to be the case for dyslexic children (Swan & Goswami, 1997). In the next section the connection between structured organization of the phonological representations and literacy development is considered.

1.6 Phonological Awareness and Reading in Hearing Children

Research evidence for the link between speech sound awareness and reading development in hearing people is strong. In fact, the link between phonological processing and the early stages of reading acquisition is described by Stanovich (1991) as, "one of the more notable scientific success stories of the last decade". The most robust evidence comes from longitudinal studies that have shown a causal connection between early phonological awareness and later literacy development (Bradley & Bryant 1983, and others). Studies investigating poor and good readers matched on reading level have highlighted a specific deficit with phonological awareness (Bradley & Bryant, 1978 and others). Training studies indicate that remediation based on linkage of phonological awareness and the corresponding written form improves the literacy skills of both normally progressing children (Bradley & Bryant, 1983), children experiencing specific difficulties acquiring literacy skills (Hatcher, Hulme & Ellis, 1994), and children at risk of reading difficulties (Borstrom & Elbro, 1997).

Studies of the link between phonological awareness and reading in languages other than English have shown that the extent to which phonological awareness is a predictor of reading attainment is related to the orthographic regularity of the language (see Harris & Hatano 1999). A large study in Norwegian assessed the predictive relationship between phonological awareness at the three levels (syllable, rhyme and phoneme) and early word reading. Höien and his colleagues (Höien, Lundberg, Bjaalid & Stanovich, 1995) found that awareness of all linguistic units were separate predictors of early word reading ability. Syllable awareness was the weakest predictor and phoneme awareness the strongest predictor. In English, which has a highly irregular orthography, rhyme awareness is an important precursor of later literacy development (Goswami & Bryant, 1990). German has a more regular orthography and rhyme awareness, although present prior to literacy instruction, makes a less significant contribution to early reading development (Wimmer, Landerl & Schneider, 1994). In highly transparent orthographies, phoneme awareness may be a much stronger predictor of reading than rhyme awareness (Goswami, 1999). Recent research into the mechanisms required for reading Chinese, which differs significantly from alphabetic orthographies, shows that phonological awareness is related to reading attainment (Hanley, Tzeng &

Huang,1999). In their review of the literature on the development of reading in Chinese, Hanley and his colleagues concluded that, *"there is now overwhelming evidence that phonological processing strategies play a crucially important role in the way that children read Chinese"*. Reading Chinese relies on visual processing to a greater extent than reading an alphabetic script, however, the authors suggest that, *"the underlying cognitive skills and strategies involved in learning Chinese and English are probably not as different as was once imagined."* (page 192)

1.6.i Orthographic Processing and Reading – Implications for Deaf Children

The findings relating to the mechanisms for reading Chinese is particularly pertinent to the way that deaf children learn to read. In the past, the assumed total reliance on logographic reading in Chinese was used as support for the view that deaf children could also learn to read and achieve mastery in reading by relying on a logographic strategy. Frith's (1985) model of reading includes a logographic stage, where words can be read according to the visual characteristics of the word envelope. According to Frith, this occurs in the earliest stage of reading development. If the logographic strategy is an important stage in early reading development then deaf children with normal cognitive skills should not show deficits in early word reading. Harris and Beech (1998) investigated early reading development in deaf children and compared their performance with hearing children of the same age who were matched for non-verbal IQ, proficiency at letter orientation and reading score at the initial assessment. After only 3 months of reading instruction the hearing group were able to recognize twice as many words as the deaf children. By the end of the first year of instruction the gap between the deaf and hearing children remained. The authors included a test of phonological awareness (this will be further discussed in Chapter 2) and performance on this test correlated with reading gain in both deaf and hearing groups. This study has been presented here because it strongly suggests that visual word recognition strategies cannot fully support word decoding in English even in the earliest stages of reading development. Goswami and Bryant's (1990) model of reading development shows how, even in the early stages of reading, pre-school phonological awareness of rhyme and alliteration (onset) is causally related to reading in hearing children.

1.6.ii The Use of a Phonological Code by Deaf Children

Conrad (1979) showed that deaf adolescents use orthographic strategies when reading, however it was shown to be a less effective strategy than phonological coding. Originating with the work of Conrad (1972, 1979), experiments based on the short-term memory paradigm have shown that deaf children are sensitive to the phonological characteristics of the word lists to be remembered (Hanson, 1982; Hanson, Liberman & Shankweiler, 1984; Campbell & Wright, 1989; Waters & Doehring, 1990). An important finding from these studies is that deaf children are able derive phonological information from the visual modality through lipreading and manually coded phonology (Leybaert, Alegria, Hage & Charlier; 1998) and from the dactylic modality using finger-spelling (Hanson, Liberman & Shankweiler, 1984). The origins of phonological awareness in deaf people and its relationship with reading will be further explored in Chapter 2.

1.7 CONCLUSION

According to Locke, vocabulary acquisition within a critical time period initiates the activation of analytical and computational mechanisms in the mental lexicon. These mechanisms act on the input (i.e. the collection of stored words and phrases) in order to derive the structure or grammar (i.e. including phonological structure). The segmental organization of phonological representations can be seen as evidence of an intact analytical and computational mechanism. Phonological awareness tasks measure underlying phonological representations. These speech based representations become increasingly segmentally organised over time, progressing from the syllable, to onset/rime and finally to the phoneme level. Phonological awareness of rhyme is an important precursor to reading in hearing children who are learning to read English. Awareness of phonemes develops partially in interaction with literacy instruction. There is some evidence from prior research to support the hypothesis that the use of a phonological code is related to reading attainment in deaf children.

Although Locke's model is given a central position in this chapter this thesis cannot purport to be an empirical test of the theory. It is not possible to test the sensitive period hypothesis directly regarding the initiation of the analytic and computational mechanism because in the UK children are not fitted with implants before the age of two. Assuming that CI candidates derive little or no benefit from conventional hearing aids prior to implant fitting, it is likely that all children fitted with implants would be unable to acquire a sufficient volume of lexical items before the age of two years to initiate the hypothesised mechanism.

The central theoretical position of the thesis is that language learning influences phonological development. Whilst enhanced auditory perception afforded through the fitting of a cochlear implant may determine the development of spoken language acquisition it cannot be the sole determinant of the structure of the phonological representations. The aim of this thesis is to assess the development of phonological awareness in deaf children who use cochlear implants. A supplementary aim is to asses the impact of the timing of implant fitting on phonological awareness taking into account the influence of spoken language acquisition on developing phonological awareness. Therefore, in this thesis I attempt to understand the determinants of phonological awareness in deaf children by exploring the relative contributions of auditory perception, vocabulary acquisition and orthographic knowledge. A final aim is to investigate the role of phonological awareness in the word reading skills of deaf children.

Chapter 2 – Phonological Awareness in Deaf Children

2.1 INTRODUCTION

In Chapter 1 Locke's (1997) theory was presented which suggests that phonological representations become increasingly segmentally organized over time, due to the acquisition of vocabulary. The increasing specificity with which phonological representations are organized is thought to account for the clear developmental pattern of phonological awareness in hearing children; syllable awareness comes first, followed by intra-syllabic awareness of onset and rime and then phoneme awareness develops reciprocally with literacy instruction. We also presented evidence of the strong relationship between phonological awareness and literacy development in hearing children. The aim of this chapter is to review the evidence for a developmental pattern of phonological awareness in deaf children. Additionally, evidence for a link between phonological awareness and reading in deaf children will be evaluated.

The origin and nature of the phonological representations of profoundly deaf participants has been a major research theme in the field during the last twenty years, originating with the work of Conrad (1972, 1979) and Dodd (1976). The contribution of Conrad's work and the short-term memory paradigm has already been mentioned in Chapter 1. In this chapter, the review begins with an analysis of Dodd's work and then focuses on an analysis of research where the tasks require awareness or manipulation of sounds. Studies are grouped into two categories:

- tasks requiring awareness or manipulation of phonological units (tests of phonological awareness)

- tasks investigating the use of a phonological code in print based tests

Prior to evaluating the literature, task design factors, which may be strongly related to performance on phonological awareness tasks, are outlined.

2.2 Phonological Awareness - Task Design

Assessments of phonological awareness in hearing children vary and differences in task design will have a bearing on the validity of comparisons made between tasks (see Goswami & East, 2000). This is especially important for assessing phonological awareness in deaf children. To elucidate this, let us consider the following rhyme awareness tasks;

a) The child is presented with three pictures, '*ring*', '*swing*' and '*duck*'. The pictures are not named and the child has to say which two pictures rhyme (Vance, Stackhouse & Wells, 1994).

b) Three words are named for the child, '*geese*', '*piece*' and '*twice*'. The child has to say which words rhyme (Frederickson, Reason, Frith, 1997).

Task A requires the child to access his/her own phonological representation for the pictured items. Successful completion of the trials relies on the phonological representations being segmentally represented at the onset/rime level, but factors other than rhyme awareness could also impact on the child's ability to complete the task. The vocabulary must be known and the child must associate the pictures with the words intended by the experimenter (i.e. thinking of 'ring' rather than 'finger' when presented with the picture of a ring). The child may, or may not refer to his/her own phonological representations in order to complete Task B. However, other factors may impact on the child's ability to detect words that share the rime unit. Words are not supported by pictures, this means that there is a greater load on short-term phonological memory. In the example given, the vocabulary used is more abstract when compared to the concrete picturable nouns in used in Task A. Furthermore, the distracter item 'twice' shares the same coda as the rhyming words thus making it a very close phonological foil when compared to 'duck', the distracter in Task A, which shares neither the vowel nor the coda with the rhyming words. The orthography of the rime unit differs in Task B, but is consistent in Task A.

The comparison of the apparently similar rhyme awareness tasks above, shows that conclusions regarding proficiency of phonological awareness will always be influenced by task characteristics and stimulus selection. Therefore, in this review of research investigating the phonological awareness skills of deaf children, close attention is paid to task design and word list construction.

2.2.i Testing Phonological Awareness of Deaf Children- Task Design

In addition to task design factors which may contribute to performance on tasks of phonological awareness, other considerations which might impact specifically on deaf children's performance should be highlighted. Let us consider the input and output demands of the rhyme tests above. Task B relies on online auditory processing; the child has to listen to words spoken by the experimenter and the verbal response has to be interpretable by the tester. Thus, listening and speaking skills are essential for this task. This may pose difficulties for the tester and the profoundly deaf participants. The presentation of items using pictures only (Task A) circumvents the auditory perceptual requirements of the rhyme task. Responses could be made in the written form by the participant, this would eliminate the difficulty of understanding the deaf child's speech. The issue of vocabulary knowledge on the picture presentation task has already been outlined above, but this is a particularly important point to stress when testing deaf participants, who typically have reduced receptive vocabularies (see Chapter 1). Presenting words in a written form, another possible methodology, also relies on knowledge of the vocabulary, but in addition, participants need to correctly decode the word. Reliance on the participant's written response means that the spelling must be recognizable as the target, by the experimenter.

Given the central role of phonological representations in phonological awareness tasks, information about the nature and robustness of the representations is a crucial factor in determining the degree of phonological awareness. Task A, above, assumes that the child has a phonological representation (however globally represented) for the items. Performance on the task reflects the degree to which awareness of rhyme has developed. This is assumed to be closely associated with the degree to which phonological representations are segmented at the level of onset/rime. It is assumed that the words 'hat, cat, fat', (which rhyme for the adult) will be made up of the same phonemic units for the child. This assumption is not a dubious one when testing hearing children whose speech and language skills have developed so that their spoken output of the words matches the adult form. However, due to different acoustic input, the phonological representations of deaf children are likely to differ considerably compared to hearing adults. Two words that rhyme for a hearing adult may not necessarily rhyme for a deaf child or deaf adult. If this is true, then poor performance on a rhyme task may reflect the deaf participants' **different phonological representation**, rather than poor awareness or representation of the rime unit per se.

We have outlined some of the task design factors that need to be considered when testing deaf children's phonological awareness. We begin the review of current literature by looking in detail at the pioneering work of Barbara Dodd. Studies are then reported according to the size of the linguistic unit under investigation (syllable, rhyme and phoneme).

2.3 The Work of Barbara Dodd

Barbara Dodd was the first researcher to take a developmental perspective on the speech of deaf children. Both her developmental perspective and the conclusions about the foundations of phonological representation in deaf children laid a foundation which supports much of the research that will be presented later. In this section we review the two papers on which Dodd's theory about the primacy of lipread input for the development of phonological awareness are based.

In 1976, Barbara Dodd investigated the phonological systems of deaf children. A group of 10 profoundly deaf children, (mean CA 11 years), were given pictures of familiar objects to name. Their phonetic inventories and phonological processes were then analysed. Dodd found that the deaf child's phonological system was partially rule governed and characteristic of delayed phonological development rather than being disordered. In a second experiment, she tested eight older profoundly deaf participants (CA 14 years, 11 months). She showed that six out of the nine phonological processes evident in the younger group, were also present in the older group of deaf participants.

Two processes common in the younger group, but not evident in the speech of the older group, were simplifying processes that change the number of syllables of words. These are; weak syllable deletion (the unstressed syllable in a multi-syllabic word is deleted 'banana' – 'nana') and epenthesis, (a vowel is inserted in between a cluster of sounds which would have the effect of increasing the number of syllables in a word 'flower' – 'felower'). Reducing clusters of sounds was a process found in the younger and the older groups. The processes affecting the representation of **syllables** disappeared with development in this cross sectional study, but processes involving the substitution or deletion of individual phonemes were still characteristic of the speech of the older deaf participants.

An analysis of the individual phonetic inventories, (i.e. the number of speech sounds used by each deaf child), led Dodd to discount the notion that the phonological systems of the deaf were derived from residual hearing, since, "the phones produced did not fall neatly into any particular frequency bands". She instead concluded that deaf children derive phonological information from lipread input.

2.3.i Reading and Repeating Nonsense Words

In order to test the predictive validity of the phonetic and phonological systems of deaf children, the older group of profoundly deaf adolescents were asked to read and repeat nonsense words. These nonsense words targeted the sounds and phonological processes that were evident in the speech of the participants in the first study. Children were asked to read a set of nonsense words, they were then asked to repeat the same set of nonsense words spoken by an experimenter. Dodd's hypothesis was that different inputs (i.e. reading versus lipreading) would lead to different speech outputs "because sounds which are difficult to lipread will be produced differently according to input". There is a suggestion here that the child's knowledge of grapheme phoneme conversion rules would lead to a disambiguation of the target sound in the read condition. A clear theoretical rationale for the different output expected depending on the variation of input is not provided. This renders interpretation of the differences difficult. Dodd reports that, "most of the phonological features were unaffected by the nature of the input". If a child reduced the nonsense word 'kwan' to 'kan' in the lipread condition, he or she did the same in the read condition. This led Dodd to suggest that the "phonological systems acquired by the deaf are stable". The phonological stability concerns the **phonological processes** rather than the individual speech sounds. Dodd did find that the written form seemed to reduce the errors in production of the velars /k/ and /g/. Phoneme production was facilitated in the read condition and this suggests that there was some instability in representation at the level of the phoneme. The velar sounds are difficult to lipread and Dodd maintains that this is the reason why both groups of deaf children had difficulty acquiring them. She used these data to argue that lipreading was the "**primary source**" of phonological information for profoundly deaf children.

Dodd's findings are limited by several methodological factors. The numbers of children studied was small (exp 1 - n=10, exp 2 n=8). Furthermore, whilst [k] and [g] are difficult to lipread, their formant transitions, especially when occurring in the coda position, also make them difficult sounds to hear (see Chapter 1). The phones, 'th', as in 'thing' and 'th', as in 'that', are highly visible, making them 'easy' for deaf people to see, but difficult to hear. However, these were amongst the commonest phones missing from the phonetic inventories of the deaf group. Six out of the ten children studied had failed to acquire these sounds. This is not discussed in the paper. A condition where the deaf participants were asked to repeat nonsense words which were spoken, but which they were unable to lipread, would have added an interesting dimension to this study. The results from such a task, together with the results from the lipreading alone condition, would aid understanding of the interaction between residual hearing and lipread inputs in the ontogenesis of the phonological systems of the deaf.

2.3.ii Nonsense Word Spelling Task – Dodd 1980

As part of a broader study, Dodd (1980) gave deaf participants a nonsense word spelling task. Twelve profoundly deaf adolescents (mean CA 14 years 5 months) were asked to both repeat and spell nonsense words. Like previous investigations by Dodd, she was interested in investigating the differences between output depending on task demands (i.e. written versus spoken output). Participants were told that they were to listen to nonsense words and were given the following instructions "I want you to say the word that I say, and then write it down". The status of the deaf participants' hearing aids as being either turned on or turned off is not reported. Twenty-four legal nonsense words were used, half had clusters in the initial position (CCVC) and half had clusters in the final position (CVCC). The stimulus list is not provided, but the author states that "only those nonsense words were used that had an unambiguous phoneme-grapheme relationship". The written outputs were analysed and spoken outputs transcribed. The analysis from the transcriptions and the written form was of the consonant phonemes only, vowels were not considered.

The total number of possible correct phonemes was 72. The deaf group was able to achieve 40% correct in the written response and 46% correct in the spoken version. The difference between these scores was not significant. The qualitative analysis of errors revealed some interesting patterns with regard to inconsistent responses in the spoken and written forms. Responses for each word in the written form and spoken form were compared. This analysis showed that one third of consonant phonemes were inconsistent. For instance, a nonsense word may be repeated incorrectly (i.e. target 'teek', the response "ti") but may have been spelled correctly, "teek". The patterns showed that inconsistencies involved deletion of sounds in speech that were present in the written form. For example, when repeating the target 'vomp', the coda ('mp'), was often missed off, but it was included in written output. This suggests that the participants **were perceptually aware of the coda**, but that they were failing to signal it in their own spoken output. In fact, the participants often correctly perceived the differences between the sounds 'm' and 'b', since they represented these phonemes correctly when spelling the nonsense word, but the transcribers did not detect a difference in their spoken output. The development of phonologically orientated assessment of the speech of deaf people (Parker & Kersner, 1997) has highlighted the fact that phonological contrasts made may go unrecognized by transcribers because contrasts are made in a different way. A detailed phonetic transcription might have revealed that the consonant cluster "mp" was marked, for example, by increasing nasal resonance over the vowel. Thus, a phonological contrast could have been signaled, but the transcribers failed to notice this because they were only focusing on segmental aspects of speech, comparing the speech of the deaf with that of the hearing adult.

Summary

With the benefit of hindsight, Dodd's conclusion regarding the organization of the output systems; that spoken and written output, "are organized separately, and that the strategies governing the generation of the two outputs differ", is difficult to support. However, Dodd's work has been very influential in the field. Her results show that profound hearing loss does not preclude the development of a rule based phonological system and that the development of a rule based phonological system is, to some extent, independent of input modality. The way in which the speech of deaf participants was transcribed and analysed, (i.e. based on normative data of hearing adults), may have meant that the role of residual hearing in the development of phonological systems of deaf people, may have been under estimated.

2.4 Phonological Awareness in Deaf Children and Adolescents

Studies reported in this section are reviewed in detail because conclusions from them aid our understanding of the nature of the phonological representations of deaf participants, and their abilities to show awareness of phonological units.

2.4.i Syllable Awareness

Sterne and Goswami (2000) were the first researchers to investigate awareness of syllables in English speaking deaf children. In a developmentally orientated investigation of phonological awareness, the authors were interested to see whether deaf children showed the developmental sequence in phonological awareness from the syllable, to the onset/rime and finally the phoneme level. In order to assess the development of syllable awareness a length judgement task was devised in which children were asked to judge whether pairs of words presented pictorially were the same length or different. Care was taken to control for written frequency of the words. The congruency of orthographic (i.e. number of letters) and phonological (i.e. number of syllables) length was manipulated. The pair 'telephone/bowl' is **congruent** since the word with the greater number of syllables also has the greater number of letters. A pair such as 'piano/elephant' is **incongruent** because the words have the same number of syllables but differ in orthographic length. The pair 'hair/baby' is also **incongruent** because the words have a different number of syllables but the same number of letters. If deaf children rely on orthographic knowledge to make length judgements they would make more errors on incongruent pairs. They would be likely to reject 'piano/elephant' as sharing the same number of syllables and say that 'hair/baby' are the same word length because they have the same number of letters. The experiments were presented on a computer and the pictures used in the experiment were pre-tested. The mean age of the fifteen deaf participants was 11years 9 months and their mean reading age was 7 years 2 months. A test of non-verbal reasoning was administered which showed no statistical differences between the deaf group, their chronological aged matched controls, or their reading level matched controls. Audiometric information on the deaf participants is not clearly defined, *"most children were severely or profoundly deaf"* (Sterne, 1996).

The results showed that the deaf children were above chance level on this task and performing at a level equivalent to their hearing, age matched controls. This study shows that syllabic representation is well established and that deaf children can demonstrate awareness of syllables when making judgements based on their own phonological representations. All groups of children showed a congruency effect suggesting that orthographic knowledge was recruited to aid phonological judgements. In order to be sure that their finding regarding syllable awareness can be generalised to other deaf children, more information about the sample is necessary. In particular, the sampling procedure and the number of children excluded from the study, due to insufficient vocabulary knowledge, needs to be known. It is possible, that this result is only representative of deaf children with advanced language skills.

2.4.ii Rhyme Awareness

Dodd and Hermelin (1977) investigated rhyme awareness using nonsense syllables. They were particularly interested in assessing the role that information derived from lipreading may play in the development of rhyme awareness. For example, in one experiment (Experiment 3) a group of profoundly deaf boys (n=13, mean CA 13 years 2 months) were asked to listen to two nonsense words and say whether they rhymed or not. Rhyme was not defined, one example of a rhyming nonsense pair was provided. The results showed that performance on the task was above chance level (set at 50% correct). Place of articulation of the final phoneme was found to have an effect on error rates, with fewest errors made on rhyming pairs where the final consonant was highly visible (e.g. 'gaf/taf'). In the non-rhyming pairs most errors were made when the final consonants were in the same place of articulation (e.g. 'kef/plaf). The stimulus lists were made up of just 8 pairs of rhyming nonsense words in each set (i.e. 8 rhyming word pairs and 8 non rhyming word pairs). Within these groups, only 3 items in the rhyming group ended in highly visible phonemes and in the non-rhyming group, only 3 items shared the same place of articulation. The authors use this data to support their view that deaf participants "were **primarily** dependent on visual input from lipreading to gain phonological information". Their conclusions were based on results from a small number of trials where the sets, aimed at investigating the role of lipreading in rhyme awareness, was small. In order to support their strong claim regarding the 'primary' source through which deaf children acquire phonological information, the effect should have been replicated with larger sets.

As part of a wider study investigating the ability of the deaf to use a phonological code during reading, Hanson and Fowler (1987) examined rhyme judgement in deaf college students (n=16). Their performance was compared to hearing controls. Participants were asked to judge whether two written words rhymed. Rhyming pairs shared the same spelling (e.g. mark/dark), but non-rhyming pairs had the same orthographic rime (e.g. gone/bone). Deaf participants were able to make correct rhyme judgements, but they made many errors on pairs that looked like they rhymed, but did not sound the same; judging that 'gone' and 'bone' rhymed. Judgements on the rhyme status of these pairs were not significantly above chance level. An explanation of rhyme was not provided. The presentation of the pairs in the written form, may well have biased the participants towards using an orthographic strategy, especially since no clear definition of rhyme was given. Correlations between speech intelligibility and rhyme judgement were significant, so that the more intelligible the speech the less likely participants were to say that pairs such as 'gone/bone' rhymed. There are some methodological weaknesses regarding the set of non-rhyming words, which may have led to an underestimation of the rhyme awareness of the deaf participants. In order to construct a list that shares the rime spelling yet differs in phonological rime, the authors used words where the codas were the same and vowels, in nearly all cases, were very close phonologically. Rejecting 'move/cove' as non-rhyming was a difficult phonological decision, the deaf group's difficulty with these pairs does not only reflect orthographic interference. The methodological weaknesses in list construction may have led to an underestimation of the rhyming skills of deaf participants and to an overestimation of their reliance on orthographic knowledge when making phonological decisions.

In a second experiment, the format of presentation was changed. A rhyming pair (e.g. done/none) and a non-rhyming, but similarly spelt pair (e.g. bone/gone) were presented on the same screen. Now the participants had to identify which of the word pairs rhymed. This modification was designed to "force" the deaf participants to use phonological information rather than orthographic information to make rhyme judgements. No training or definition of rhyme was given to the participants, but the instructions were changed so that accuracy over speed was emphasized. In this condition, deaf participants scored above chance level (64.1% correct), but their scores were not in line with their hearing controls who were at ceiling on the test. Under this revised condition, there were no significant correlations between speech intelligibility or reading achievement and the rhyme judgement task. Hanson and Fowler claim that the results indicate that deaf participants can develop a phonological code and make correct rhyme judgements. The development of this code is not necessarily related to or reliant upon good speech skills; the participants in the experiments were all American Sign Language users.

A year later Campbell and Wright (1988) published their findings regarding rhyme judgements in deaf adolescents. Like Hanson and Fowler they were interested to know the extent to which deaf children were relying on spelling regularities to support rhyme judgements. Congruency was manipulated in two ways. Rhyming pairs either shared the spelling (e.g. "dog/frog" – a congruent pair) or the spelling differed (e.g. "hair/bear" – an incongruent pair). Congruency of **non-rhyming** pairs was also manipulated by devising two sets of words. Congruent non-rhyming words are those where the spelling of words gives the right decision (i.e. that pairs do not rhyme, e.g. "clock/clown"). Incongruent non-rhyming pairs share an orthographic rime, but the words do not rhyme (i.e. "comb/bomb"). Thirty-two profoundly deaf children took part in the study (mean CA 14 years 8 months, mean reading age 8 years 5 months). Two rhyme judgement tasks were administered, these were; a picture task and a task where words were presented in the written form. Children relying on orthographic knowledge to complete the task would be likely to make more errors on the incongruent words pairs, judging that 'hair/bear' do not rhyme, and saying that 'comb/bomb' do rhyme.

The findings show that both deaf and hearing groups were less accurate when making rhyme judgements on the incongruous pairs (hair/pear, comb/bomb). The reading level matched hearing group was at ceiling on the picture task and the effect of congruency was only significant in the written word task. However, the deaf group was subject to the congruency effect on both picture and word presentation. Performance on the congruent word pairs was above chance level in the deaf group, but their rhyme judgement ability on incongruent pairs was at or below chance level. The deaf children's ability to make accurate judgements in the incongruent conditions was significantly correlated with their reading levels. Furthermore, high correlations between their expressive speech and lipreading and the incongruent conditions were reported. The authors conclude that the development of phonological representation at the level of the rime was not available to deaf children if they relied solely on acoustic and lipread inputs, since their rhyme judgement in the incongruent sets was at chance level.

However, there are some important differences between the congruent and incongruent sets which are not discussed by Campbell and Wright. The phonological judgements on incongruent non-rhyming word pairs were more difficult than the phonological judgements on the congruent non-rhyming pairs. The incongruent non-rhyming pairs (e.g. comb/bomb), although not rhyming are very close in phonological terms. All, but one of the word pairs share the coda and the vowels have similar formant frequencies. For example, in the pair "foot/boot" both vowels have a similar lip pattern and there is no difference in formant frequency, the vowels only differ in duration. Deaf children could have been making errors on the incongruent non-rhyming words (i.e. saying that they rhymed) based on the phonological similarity of the items rather than the orthographic similarity. The degree of phonological similarity of the pairs in the congruent non-rhyming list is not equally matched, for instance only 4 pairs out of 13 share their coda. There are additional differences between the word lists that may have affected the deaf children's performance in the task. Eight of the thirteen word pairs in the incongruent rhyming list have a rime unit that consists solely of the vowel. The congruent word list contains only one pair with this rime structure. It may be easier to make rhyme judgements when the number of phonemes in the rhyme increases, so that 'box/fox' (CVCC), may be an easier rhyme judgement because of the increased number of phonemes in the rime compared to 'pear/chair' (CV).

These points are important when considering the strong negative conclusions of Campbell and Wright about deaf children's rhyming abilities. As in the Hanson and Fowler study, the rejection of the non-rhyming incongruent word pairs relied on awareness of the vowel. Given this important difference between the congruent and incongruent non-rhyming words, we cannot be sure whether the deaf groups performance on the incongruent words was deleteriously affected because they were relying on spelling knowledge or because of the more difficult phonological judgement required. Separate reporting of the results from the four word pair types may have shed some light on this.

Sterne and Goswami (2000) measured the rhyme awareness of 14 profoundly deaf children (mean age 10 years 5 months, mean reading age 7 years 10 months) and compared their performance to a group of reading level matched control hearing children. Children were given a picture pre-test to ensure that the words used in the experiment were known. Training in rhyme was also given before the experiment, in fact the children received 16 practice trials in total before the experiment was presented. Sterne and Goswami chose to use a matching to sample task using pictures, with a choice of 2 items, the rhyming word and a distracter. Different distracters were included in order to investigate the origin and organisation of phonological representations. There were five different sets based on the relationship of the distracter to the target (unrelated, lip-shape, initial consonant, initial consonant cluster, onset-vowel). The words were not spoken for the children. Half the trials in the test consisted of rhyming words that had the same orthographic rime (e.g. clock/sock) and half had different spellings (e.g. goal/bowl). Results showed that the deaf group's performance was better with the orthographically matching rhymes, but performance on the orthographically dissimilar rhymes was still above chance level. When compared to the rhyme judgement ability of their reading level matched controls their performance was significantly worse.

The analysis of the performance by distracter set indicated that the deaf group's performance was significantly better when the distracter was unrelated to the target. All other distracter types induced a deleterious effect on rhyme judgement. The phonological distracters were divided up into 5 sub sets, however, a lot of overlap exists between the sets. For instance, the onset vowel distracter sometimes shared the same vowel phoneme (goal/goat), but in other cases only the vowel orthography was similar (shoe/shorts). Here, 'goat' could also be described as lip-shape distracter to 'goal' since the vowels in the words have similar and distinctive lip shapes. In fact, it is a better lip-shape distracter than some items in the lip-shape set, (e.g. target 'stairs' with 'whale' as the lip shape distracter). In this example, neither the vowel nor the initial sound is similar in lip shape. Despite these errors in word selection, some lip-shape distracters were good and an analysis of the best trials containing lip-shape distracters showed that the deaf participants were more likely to choose a lip-shape distracter than an unrelated distracter. Trying to separate out lip-shape and phonological similarity is almost impossible in English. A good lip-shape distracter (i.e. where the vowel is included) will also be a good phonological distracter because similar lip shape means that the vowel, in terms of sound, will also be similar. The presence of a distracter that shared the consonant cluster with the target word produced fewer errors than the other phonological distracters. This may reflect the fact that clusters are particularly hard for deaf children to represent (Dodd, 1976). The specificity of the phonological representations of clusters may be fuzzy and unstable, or just under specified. If this is the case performance would not be expected to be affected by this group of distracters as much as a singleton onset cluster that was well specified.

A relationship between reading level and rhyming ability is not reported in this study, but Sterne and Goswami show that deaf children are capable of making correct rhyme judgements that are not solely reliant on spelling knowledge. Furthermore, phonological distracters deleteriously affected rhyme judgement suggesting that these children adopted a phonological strategy when attempting to make rhyme judgements. In order to be confident that this finding can be generalized, further information about the selection of the sample and the degree of hearing loss is necessary.

2.4.iii Cued Speech and Rhyme Awareness

Cued speech (CS) was devised by Cornett (1967). In CS, the lip shape of the speaker is complimented by manual hand cues. The position of the hand, the hand shape together with the lip shape are the three parameters of CS. The use of these three parameters provides unambiguous information about vowels and consonants. Cued speech was devised as a way to help deaf children perceive speech. The study of the effects of the use CS in phonological awareness tasks provides an opportunity to evaluate the nature of phonological representations of deaf people.

The effect of age of exposure to cued speech on rhyme judgement was investigated by Alegria, Leybaert, Charlier and Hage (1992). A group of deaf children exposed to cued speech early (CS+, n=18, mean CA 9 years 11 months) and a group who were exposed to cued speech at school (CS-, n=48, mean CA 10 years 9 months) were compared with hearing controls (n=15, mean CA 9 years 10 months). The authors manipulated the orthographic similarity of rhyming words, but in addition they included a list of non-rhyming words that had shared lip patterns. The rationale for this control was that if the primary source of phonological information for deaf children was gained through lipreading, then they should make rhyme judgements on the basis of similar lip patterns rather than on the acoustic similarity of the vowel and coda. Pairs of drawings were presented to the children and they had to say whether two pictures rhymed or not. The results showed that both deaf groups were able to make rhyme judgements which were above chance level, but that the children exposed to cued speech early were less likely to be affected by the lack of spelling similarity of rhyming words. In fact, the CS+ group's rhyme judgement performance remained at ceiling even when the orthography of the rimes was not shared. The CS- group were more heavily influenced by the effect of shared lip patterns, scoring 59% correct, when chance was 50%. This partially confirms the view that profoundly deaf children rely on information from the lips to derive phonological information. It also supports the view of others (Campbell & Wright, 1988) that the sole reliance on lip patterns and acoustic information does not enable the development of phonological representations specified at the onset/rime level. The finding that the children exposed to cued speech early were able to perform at ceiling on this task and 'override' the conflicting orthographic information and lip-pattern distracters suggests that these children have internal representations that are specified at least at the onset/rime level. The duration of exposure to cued speech was not balanced across the two deaf groups, the CS+ group had longer exposure. This makes it difficult to assess whether the timing of the introduction of cued speech or the duration of use was responsible for the development of well specified phonological representations.

Whilst it appears that early introduction of cued speech goes a long way to facilitate the acquisition of a phonological system, there is a methodological weakness in these studies that may mean interpretations regarding the benefits of cued speech are over estimated. Can we assume that deaf children who receive cued speech early and deaf children who receive cued speech late are the same in all respects, other than the time at which they were exposed to cued speech? It would seem highly probable that important differences exist between these two groups of children. Factors such as; the age of diagnosis, the onset and progression of the deafness and the family hearing status (deaf children of deaf parents versus deaf children of hearing parents) are likely to have an effect on the timing of intervention for a deaf child. These factors will bear on language development and may bear on phonological awareness (see Chapter 1).

In a further study, specifically aimed to investigate the extent to which timing of exposure to cued speech was responsible for improved rhyming skills of deaf children, Charlier and Leybaert (2000) extended the number of groups of deaf children studied. As well as having CS+ and CS- groups, they also studied the effects of early versus later exposure to sign language. In addition to these four groups they also included a group of deaf children educated in the oral tradition who were not exposed to cued speech. A hearing control group of chronologically younger children was also studied. Entry criteria into the study was strict. The children were required to classify five pairs of rhyming words correctly and to provide an explanation as to why the words rhymed. Thus, children in the study possessed explicit awareness of rhyme. It was found that younger children, below the age of 6 years, found this difficult. Five children from the CS+ group, 3 from the hearing group, 5 older children from the CS- group and 1 child from the oral group, were excluded on this basis.

Groups

	N	**Mean CA**	**Mean Reading**[a]	**SIR**[b]
CS+	16	10 years 1 month	5.3	3.9
(duration of use 28 months)				
CS-	18	12 years 7 months	3.2	3.4
(duration of use 56 months)				
Oral	29	13 years 3 months	3.4	4.0
SL+	12	10 years 4 months	3.3	2.9
SL-	20	10 years 1 month	3.7	3.0
Hearing Controls	12	8 years 7 months	-	-

[a] reading was rated by the child's teacher of the deaf on a scale from 1, very poor, to 6 being perfect

[b]SIR – speech intelligibility rating was provided by the child's speech and language therapist (1, very poor, 6 perfect)

In addition a group of pre-readers were studied.

Pre-Reader Groups:-

	N	Mean CA	SIR
Cued Speech Early	n=5	CA 5y 6 months	4.0
Hearing Controls	n=10	CA 5y 10 months	-

The children were shown pairs of pictures and were asked to say whether the words were friends (meaning that the two words rhymed) or not friends (meaning a non-rhyming pair). The picture stimuli used in the tests were not pre-tested, so it was not certain that the children knew the vocabulary. Although the vocabulary used was taken from a list of words commonly known by young deaf children, some of these words may not have been known to the youngest children in the groups (e.g. wolf/neck). The stimuli were manipulated to examine the effect of orthographic similarity and lipread similarity on rhyme judgements.

The results showed that the CS+ group differed significantly from all the other deaf groups. All deaf groups, apart from the CS+ group had significantly poorer performance on the orthographically different rhymes. The effect of lipreadability similarity was less influential than the orthographic variation, but again, the CS+ group were less affected by this distracter. Interestingly the pre-readers (CS+ and hearing children only) were indistinguishable from each other. The results from the pre-readers showed that <u>both</u> groups were significantly affected by the lip pattern distracter. Correlational analyses between factors such as age, speech intelligibility and hearing loss revealed different links for different groups. The link between speech intelligibility and rhyme judgement was present for the CS+ group and the oral group; the higher rated intelligibility the better the rhyme judgement, but this was in the opposite direction for the two sign language groups. Correlations between reading level and rhyme judgement are not reported in the paper, although ratings of reading level were collected.

This study indicates that it was the early introduction of cued speech, rather than early linguistic advantage, that was responsible for the superior rhyme awareness in these deaf children. Duration of cued speech use can be ruled out as a contributing factor since the CS- group had longer exposure than the CS+ group. The fact that deaf pre-readers were indistinguishable from the hearing pre-readers both in terms of overall performance and susceptibility to lipread similarities is remarkable. It would be interesting to extend this study to include a greater number of children and to take a longitudinal perspective, examining the effect of developing orthographic representations on phonological judgements. This would aid interpretation of the previous literature and develop our understanding of the nature of the link between orthographic factors and phonological factors in the development of phonological awareness.

Harris and Beech (1998) investigated the onset/rime awareness skills of young deaf children at the beginning stages of reading development. The deaf children (n= 24, mean CA 5 years) were matched with hearing controls (n=56, mean CA 5 years) on non-verbal IQ, letter orientation skills and reading level. They used a picture based oddity task to measure onset/rime awareness. There were three word sets investigating phoneme awareness at the initial position, medial position (the vowel) and the final position (the coda). The format of presentation for all three levels was the same. The child was shown a picture of the target word, which was also named by the experimenter, then two more pictures were presented and named. The child had to choose the word that shared either the initial, medial or final phoneme with the target picture. For example, in the initial phoneme set, 'hat' was the target word, two more pictures were then presented and named; 'tap' 'hand' and the child was asked to indicate which word "had a name like the first one". The words were pre-tested in a pilot study so that only pictures that were known by a different group of deaf and hearing 5 year old children were used. Children's reading levels were assessed and a measure of reading gain over a period of 24 months was used to assess the link between phonological awareness and other measures of speech and language proficiency. The data from all three sets, initial, medial and final, were collapsed. Results showed that the deaf group was less accurate than the hearing group on the task of phonological awareness, scoring only just above chance level (60.1% accuracy). The hearing group scored at 81% accuracy. There was a significant correlation between phonological awareness and reading gain in both the deaf and hearing groups.

There were large individual differences in the deaf group, with 15 children out of 24 making 8 or more errors on the phonological awareness test (chance level was 9 errors from a total of 18 trials). Children with severe hearing losses and profound hearing losses were grouped together. An analysis looking at the effect of degree of hearing loss may have been enlightening. It would be expected that the children with more residual hearing would do better than the profoundly deaf children, if degree of residual hearing is important for phonological awareness. It would also be interesting to know if there were advantages from lipreading. Lip cues could have benefited awareness of sounds in the initial and medial word positions compared to the coda.

2.4.iv Rhyme Generation

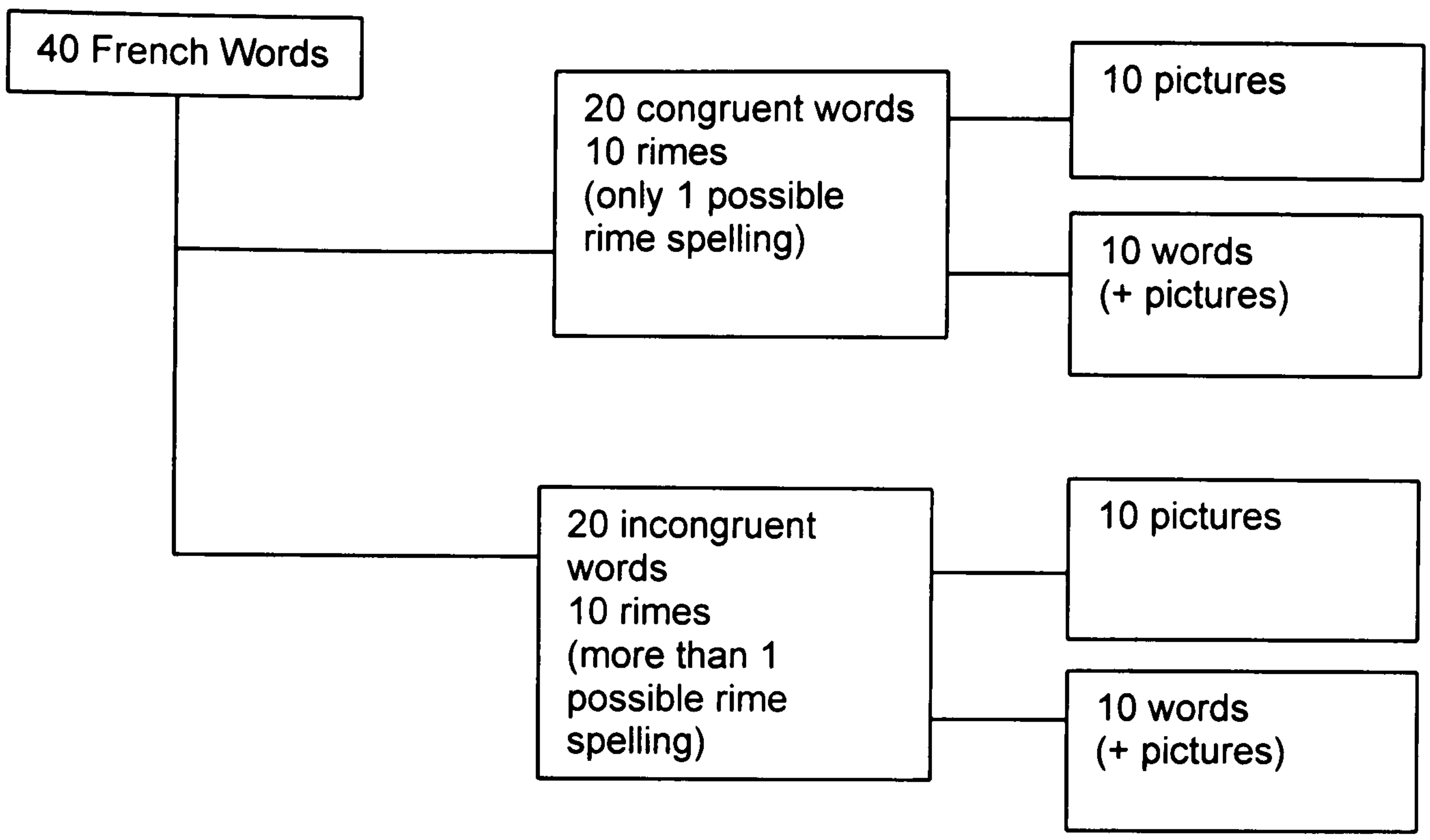
The first study to investigate the rhyme generation abilities of the deaf was carried out by Hanson and McGarr (1989). Deaf college students (n=15) were asked to write down words that rhymed with a written target. There was no hearing control group. It is reported that only a few participants asked what 'rhyme' meant. No definition was given, but a rhyming pair, "blue two" was provided. The 50 target words included 25 different rime units. Each rime (i.e. /oo/) had a pair of non-orthographic rhyming words as targets (e.g. "new blue"). No rationale was given as to why pairs of non-orthographic rhymes were used in the experiment. This may have had the effect of generally inflating the non-orthographic rhyme generation responses that participants made. It may also have had an effect on the actual response, the recall of "new" to the target "blue" may have been primed by the presentation of "new" as a target itself earlier in the test.

The written responses of the participants were classified into orthographic rimes and non-orthographic rimes. Out of all the responses written by the deaf group only 50% rhymed with the target. Of these only 15.7% of the rhymes were non-orthographic (e.g. tie/sky). There was a range of abilities in this deaf group with clear individual variations both in terms of the number of rhyming responses a participant made, and the reliance on the use of an orthographic strategy to generate rhymes. Although, it was "apparent that no subject relied solely on the orthographic strategy" since the percentage of non-orthographic rhymes ranged from 10.6% to 66.7%. Correlations between reading scores, the number and type of rhymes generated (i.e. orthographic versus non-orthographic) and speech intelligibility did not reach statistical significance. Errors were classified into categories of; vowel errors, orthographic errors, speech related errors or unclassifiable. The category containing the greatest proportion of errors was vowel errors. The 'vowel errors' contained the same vowel as the target word, but the coda was erroneous (pail – pay) or omitted (peace - bee). This suggests evidence of a global phonological processing strategy based on residual hearing and/or lipreading. The acoustically salient portion of words accessible to the deaf is the vowel, the vowel is also salient through lip shape. Lip-pattern errors, (i.e. producing 'one' as a rhyming word for the target 'want') were infrequent. This indicates that lip patterns were not the primary source of phonological information on which these deaf participants were generating rhymes.

There are some methodological weaknesses in this study which may limit the conclusions that can be drawn. No clear definition of rhyme was provided to the participants and the use of the written form in presenting targets may have influenced the use of an orthographic strategy by the deaf participants. The proportion of non-orthographic rhymes generated could have been largely due to possible priming effects of a non-orthographic rime in the experimental set (i.e. producing 'new' as a rhyme for 'blue'). These will have contributed to the percentage of non-orthographic rhyme responses. Scoring homophones (e.g. sale/sail) as correct rhyme responses is questionable, the production of a homophone does not necessarily indicate intra-syllabic awareness at the onset/rime level. The authors conclude by saying that their results "provide evidence that a severe-profound hearing loss does not preclude an ability to rhyme.........." but that, "the results of this study should not be taken to indicate.... that rhyme ability is necessarily characteristic of deaf individuals".

Charlier and Leybaert (2000) report a rhyme generation study as part of their investigation into the effects of the age of exposure with cued speech on the rhyming skills of deaf children. Four groups of twenty children were tested. The CS+ group (mean CA 11.4), CS- group (mean CA 16.10) were matched to groups of hearing children according to reading level (mean CA 10.6 and 10.4 respectively). The effect of spelling congruency was investigated by manipulating the spelling of rimes. Half of the rhymes had unambiguous spellings, i.e. the rime in the word 'POMME' 'omme' /om/ only ever has <u>one</u> spelling and half the target rhymes had several spelling units (e.g. the rime unit in the word 'FILLE ' 'ille' /I/ has several spellings). Pictures and written words were presented, half of the stimuli were presented in picture form and half were presented as words accompanied with pictures where necessary. The number of orthographically different rhymes generated to the ambiguous targets would indicate the use of phonological rather than visual based strategy to generate rhymes. The participants saw either a word/picture or a picture and they were asked to write down two words that rhymed with the target. In the case of the picture alone condition, the children were not told what the target was, no information on the associative strength between the picture and the intended target is provided by the authors. The stimuli list was constructed so that there were only 10 rhymes targeted, with a word and a picture from each rhyme neighborhood.

Stimuli



The experiment was divided into two sessions. The picture presentation was given first, presented with a mix of congruent and incongruent items, followed by the picture/word items. This meant that in the picture/word task each phonological rime had already been primed (assuming of course that the child accessed the rhyming phonological form for that picture). Therefore, superior performance might be expected on the word/picture condition compared to the picture alone list.

The number of orthographically different rhymes versus orthographically similar rhymes was scored. Errors (i.e. all non-rhyming words that were generated) were judged according to how phonologically similar and orthographically similar the words were to the target word. Results were compared for each deaf group and their hearing controls. The CS+ group differed from their hearing controls both on accuracy of rhyme generation and on the effect of congruency. They made more erroneous rhyme generations for the incongruent words/pictures than for the congruent pictures. Overall, the CS+ group outperformed the CS- group. Interestingly, the hearing status of the CS- group (as a group they were less profoundly deaf than the CS+ group) was related to their ability to produce rhymes, this relationship did not exist in the CS+ group. Furthermore, degree of residual hearing was related to the CS- group's ability to produce correct rhyme responses on incongruent rimes. When reading level was controlled, the CS+ group still showed significantly better performance on the rhyme generation when compared to the CS- group. Types of response showed that the hearing group produced the biggest proportion of orthographically different rhymes, the CS+ group produced roughly 50/50 and the CS- group produced mostly orthographically similar rhymes. Although reading level was assessed in this study, no direct relationship between rhyme generation and reading is reported.

The hearing group matched on reading level to the CS+ group, were not affected by the congruency of rime spelling and actually produced a higher percentage of correct response in both presentations, of the incongruent rhymes. However, the hearing group who were matched to the CS- group did produce fewer correct rhymes to the incongruent targets in the printed word condition (94,4% in the congruent word condition and 86,8% correct in the incongruent word condition). The mean chronological age of the two groups was similar, (10.6 and 10.4 months), but the group matched to the CS- group had lower reading scores. Detailed information on the reading measure and the discrepancy between chronological age and reading level in the CS- group and their hearing matched controls is not provided. This omission hampers interpretation of this interesting difference in the hearing groups. The finding is not discussed in the paper, but it is of interest since it suggests that hearing children who have lower reading scores were affected by the orthographic status of the rhyme target.

These authors, like Hanson and McGarr, found that the largest single group of errors were concerning the omission or substitution of the coda. In the majority of cases the vowel was correctly matched. Thus a general phonological strategy based on the saliency of the vowel is again evidenced here; the children may have adopted a less specific, but no less phonological strategy, to generate responses to the targets. The negative finding between speech and rhyming is used to claim that the CS+ group were not relying on an articulatory, rhyme generation strategy, but that their rhyme generation abilities stemmed from their well specified phonological representations.

2.4.v Phoneme Awareness

Tasks designed to assess phoneme awareness have only been presented using print. There are no studies of implicit or explicit phoneme awareness in deaf children analogous to those used with hearing children. Studies that have used print based tasks to assess phonological awareness will now be presented in a developmental order starting with syllable awareness.

2.5 Phonological Coding in Literacy Based Tasks

2.5.i Syllable Awareness

Two recent studies have used literacy tasks to investigate whether deaf participants are sensitive to the syllabic structure of words. Transler, Leybaert and Gombert (1999) used a copying task. Deaf children (n=21, mean CA 10 years 6 months) and hearing participants (n= 19, mean CA 7 years 7 months), had to copy real French words and non-words, which varied in syllabic length, from cards that were presented behind them. The children were filmed whilst copying. The experimenters recorded the part of the word that was copied in one glance. The experimental hypothesis being that, if deaf children are sensitive to the syllabic structure of words, then they would copy whole syllables in one glance. The hearing children were matched to the deaf children using a lexical decision task. The groups were equivalent on the number of items that were correctly identified as being words or non-words. There was no measure of reading level. The results showed that the deaf and hearing children, matched for lexical level, were chunking units, to copy, in syllables. However, when the non-words were considered, in which the orthographic and phonological syllable boundaries did not coincide, the deaf children did not show sensitivity to the phonological syllable boundary, but the hearing children did. The authors conclude by saying that "orthographic units were more easily and more rapidly processed by the deaf children .... than the corresponding phonological units".

Olson and Nickerson (2001) studied the sensitivity of deaf college students (n=22), whose academic level is above that of the general deaf population, to syllable boundaries using a visual task. Experimental work has shown that when visual information is presented briefly, people often combine features of colour and form, so if a red O and a blue X is shown, people combine the features and report seeing a blue O. Prinzmetal and his colleagues (1986) used this paradigm to assess sensitivity to syllable boundaries in hearing participants. The word is printed in two colours. The place in the word where the colour changes, is either congruent with the syllable boundary or incongruent. They found that when the colour change was incongruent with the syllable boundary, participants were more likely to make errors when asked to report the colour of the letter. For example, in an incongruent trial the word 'parcel' is presented. The first two letters are coloured red 'PA', but the second half of the word is coloured blue 'RCEL' the change in colour is not congruent with the syllable boundary, which should occur on the 'C'. When the participant is asked to report the colour of the letter 'R', he/she is likely to report that it was blue. This is thought to be due to the fact that syllabic representational knowledge is strong, influencing lower level perceptual information. Olson and Nickerson used this paradigm, controlling for the frequency of the grapheme combinations at the point of the syllable boundary. Their results showed that the experimental effect was strong in deaf college students, showing that they organized orthographic strings into syllabic units. There was no correlation between the strength of the syllable effect and reading score.

Summary

The results from these two studies suggest that advanced deaf students are sensitive to the phonological syllabic structure of words. Younger deaf children showed sensitivity to the orthographic syllabic structure of words, but not the phonological structure. On the basis of these two results, we might assume that phonological sensitivity of syllables would develop over time, in deaf children. However, given the nature of the sample used in the Olson and Nickerson study, it is not possible to assume that such a development would be characteristic of all deaf children.

2.5.ii Phoneme Awareness

Sterne and Goswami (2000) used a homophone matching task to assess phoneme awareness in deaf children (n=15, mean CA 11 years 9 months, mean reading age 7 years 2 months). The same groups of children took part in their test of syllable awareness. Participants were asked to read nonsense words, one of which was homophonous with a target real word. For example, the target word 'cake' was presented as a picture, four non-words were written beneath the picture, 'caik' (the pseudo homophone), 'cail' 'saik' 'coik'. The three distracter words were varied so that they differed in either their final, initial or medial phoneme compared to the pseudo homophone. Half the pseudo homophones were made up of orthographic rime units that are present in real English words and half contained rime spellings that do not occur in written English. It was predicted that both deaf and hearing groups might use a rhyme analogy strategy to read the pseudo homophones and if so, their performance would be facilitated when the spelling of the pseudo homophones occurred in English. There were 20 trials in total.

Results showed that the deaf group were above chance level (mean number of correct responses out of 20 was 12.59), although their ability to correctly choose the pseudo homophone was significantly below that of their reading level matched controls (mean correct responses 18.31).

The status of the rime unit, either occurring or not occurring in English did not affect the performance of any groups. The errors that the deaf children made showed that they were unlikely to choose a word that differed in the initial phoneme (i.e. choosing 'saik' for 'cake'), only 8.73% of their errors were of this type. In contrast, 54.8% of errors occurred because the deaf group chose words that differed in their end phoneme (i.e. choosing 'cail' for 'cake'). Vowel errors accounted for the remaining 36.6%. Although a detailed error analysis is not provided, the authors suggest that the final errors were phonological in nature. Their conclusions appear to based on the place of articulation of the final phoneme, the example given in the paper is the choice of 'boin' for the word 'boys', the sounds [n] and [z] are both articulated at the same place in the oral cavity. An analysis of the final phoneme distracters shows that only 4 out of the 17 items (some items contained clustered codas) had the same place of articulation as the target word (i.e. 'boin' 'boys'), the remaining 13 items had visually different phonemes in the final position (i.e. 'gerf' for 'girl'). A comparison along these lines might reveal that there was an effect of place of articulation, although, comparing set sizes with such unequal numbers of trials might hamper interpretation. However, if an effect of place of articulation was detected this would strengthen the view that visual information plays a major source of input in the formation of the phonological skills of deaf children. The authors conclude that the initial onsets of words seem to be re-coded with the most accuracy by deaf children.

In Sterne and Goswami's syllable test (reported above) the same group of deaf participants were outperforming their reading matched controls, but the results from this experiment, show that they were significantly poorer on a task that required phonemic awareness. This result shows that syllable awareness precedes phoneme awareness in deaf children.

The homophone judgement task does require phonological recoding at the phonemic level; children must have well developed knowledge of sound/spelling mappings. However, in order to correctly judge which homophone matches the real word, they also need to have phonological representations that are the same as the target, which is based on the normal, adult pronunciation for that word. We do not know the specificity of the deaf children's phonological representations. The use of an auditory lexical decision task using the words in the experiment would have provided evidence on the stability and nature of the deaf children's phonological representations. In such a task, the child sees a picture of an item, (e.g. 'cake'), the experimenter says the word in different ways, some of which match the adult form (i.e. 'cake', 'ca' 'ake' 'gake'). The child has to say whether the way the experimenter is saying the word is correct. Results from a task such as this would complement the results from the re-coding task since it would further our understanding of the link between the stability and degree of specificity of the phonological representations and decoding ability.

2.5.iii Letter Cancellation Tasks

Awareness of phonemes has been examined by a number of researchers using a letter cancellation task. The child reads a passage and answers questions about it. Whilst reading, they are instructed to cross out (cancel), certain pre-specified letters. For example, Locke (1978) asked participants to cancel the letters 'c', 'g' and 'h'. Within the passage, the letters occurred in words where they were pronounced (e.g. 'curly', 'game' 'hot'), termed as 'modal forms' and the same letters occurred in words where they were not pronounced (e.g. 'chair', 'night' 'phone'), termed, 'non-modal forms'. Hearing children often failed to cancel letters that occurred in non-modal forms, but did cancel the letters when they occurred in modal form. This is because the hearing children use a phonological code when reading. Locke's results showed that deaf children, matched to hearing children of the same age, did not show the same discrepancy in performance as the hearing group. The deaf participants were just as likely to cancel letters when they occurred in the non-modal form as in the modal form. This led Locke to conclude that the deaf children were not accessing a phonological code when reading.

However, half of the deaf participants did show a pattern that was similar to the hearing controls. Other researchers have found that deaf children did fail to cross out letters when they occurred in a non-modal form (Chen, 1976; Dodd, 1987; Gibbs, 1989; and Quinn, 1981). The balance of results suggests that deaf children do access a phonological code when reading, although this may not be characteristic of all deaf participants.

2.5.iv Stroop Task

The Stroop paradigm provides a way of testing the automaticity with which phonological representations are activated. In a classic Stroop task, a participant is presented with a word, which is printed in coloured ink. The word might be the name of a colour, 'red' or 'yellow', but the ink in which the word is printed is a different colour. The participant is asked to name the colour of the ink in which the word is printed. In hearing participants, the conflict of colour name and the colour of the ink, delays reaction times and accuracy due to involuntary reading of the word. Leybaert and Alegria (1993) used a Stroop task, which they varied to include homophones of colour words (e.g. 'bloo') and pseudo words. The deaf and hearing participants both took longer to report the colour of the ink when the word was a colour homophone (i.e. 'bloo') than when the word was a pseudo word. The authors conclude that deaf children did show <u>involuntary</u> and quick access to phonological representations when presented with written material. This finding is of particular interest because it shows that phonological knowledge was activated even during an implicit reading task.

2.6 DISCUSSION

Measuring Phonological Awareness of Deaf Children

Designing tasks to use with deaf children that are good measures of phonological awareness poses many challenges. Tests must be accompanied by instructions and definitions that a deaf child can easily understand. In the majority of the studies reviewed here only limited definitions and task instructions were given. The presentation of stimuli to deaf children is problematic. If pictures are used then it necessary to ensure that the target words are unambiguously associated with the presented picture. Presenting items in a written form may influence the adoption of an orthographic strategy, thus inflating orthographic responses and leading to an underestimation of deaf children's phonological knowledge. However, it is important that any tasks of phonological awareness used with deaf children should include a way of assessing the degree to which orthographic information is relied on to make phonological decisions. Manipulating words sets to control for orthography is not easy. We have seen that in some cases controlling for orthographic knowledge made the true phonological judgements more difficult and perhaps led to an underestimation of the rhyme awareness of deaf children.

Some of the methodological limitations of the studies reviewed here are more general and commonly found in experimental research. Perhaps the two most significant factors that limit the extent to which the findings can be generalised relates to lack of information about the sample (nature and degree of hearing loss, recruitment procedures) and small sample sizes.

The Phonological Awareness Skills of Deaf Children

Syllable Awareness

The syllable awareness test of Sterne and Goswami (2000) shows that deaf children can develop syllabic awareness similar to that of chronologically age matched controls. Dodd's (1976) work showed that the phonological structure of deaf children's speech is delayed, however, phonological processes concerning **syllabic** structure develops over time. Whilst both these studies have some weaknesses, regarding generalisability and small sample sizes respectively, these limitations did not invalidate their results. Olsen (2001) found that advanced deaf college students were aware of the syllable boundaries of words, although this awareness was not related to reading skill. However, the work of Transler and her colleagues (1999) showed that in a copying task, younger deaf children were only sensitive to the orthographic syllable boundaries in words. We can conclude that deaf children can represent words in syllables and that they can show awareness of syllables, this may not be characteristic of all deaf children.

Rhyme Awareness

The most positive finding of rhyme awareness comes from Sterne and Goswami. Their study shows that deaf children can develop awareness of rhyme that is independent of orthographic knowledge. However, we are limited in our understanding of how representative this finding is. The studies of Charlier and Leybaert (2000) and Alegria, Leybaert, Charlier and Haige (1992) showed that rhyme awareness can develop when deaf children have been exposed to unambiguous phonological input from an early age. It seems that early, unambiguous phonological input leads to the development of a phonologically constructed lexicon. These participants represent a small proportion of all deaf participants. All the studies show that rhyming skills are delayed when compared to hearing children matched for reading level. We can conclude that deafness does not totally preclude the development of rhyme awareness, but it is not particularly characteristic of deaf children either.

Phoneme Awareness

The studies investigating phoneme awareness suggest that deaf children do utilise phonemic knowledge when reading. Sterne and Goswami showed that a group of deaf children had developed phoneme re-coding skills that were above chance level, although not in line with younger reading level matched controls. The results from a number of letter cancellation tasks suggest that awareness of phonemes is activated in reading. The extent to which orthographic knowledge is causal in developing phoneme awareness cannot yet be addressed.

Development of Phonological Awareness

There have been no longitudinal studies of phonological awareness, therefore, it is difficult to make any conclusions about its development over time in deaf children. It does seem likely, that deaf children rely heavily on orthographic knowledge to support phonological judgements, whether the reliance on orthographic knowledge leads to true phonological awareness remains to be seen. The developmental pattern shown by Sterne and Goswami, comparing syllable and phoneme awareness in the same participants, shows that syllable awareness was at a higher level than phoneme awareness. The data from able deaf college students shows that profound deafness does not preclude phonological awareness, but it may not be characteristic of all deaf people.

Phonological Awareness and Reading in Deaf Participants

There is no support for a relationship between syllable awareness and reading in deaf people. There was no relationship in able deaf college students who had good syllable awareness (Olson and Nickerson, (2001). Neither was there a relationship in deaf children learning to read French, where the syllable is thought to be an important unit used in early reading development (Transler, Laybaert & Gombert, 1999). The strongest evidence of a link between phonological awareness and reading in deaf children comes from the longitudinal association of onset/rime awareness and reading, reported by Harris and Beech (1998). This important finding showed a link between phonological awareness and early reading development in young deaf children. Campbell and Wright (1988) also showed an association between true rhyme awareness and reading in an older group of deaf children, but other studies, where reading measures were taken, have either not reported the correlation or reported a null finding. A print based task showed that deaf readers are able to decode words at the level of the phoneme (Sterne & Goswami, 2000). Although it is difficult to be specific about the linguistic unit under investigation in a number of other print based tasks, the results generally showed that that phonological codes are activated in deaf children and adults during reading tasks.

CONCLUSION

The work of Jacqueline Leybeart and her colleagues in Brussels has shown clearly that the development of a phonological system is not dependent on auditory experience alone. This work is important because it shows that phonological units are not sounds, but a-modal abstract units. The work from this group has also shown that perception does not equal representation. Children who use cued speech have easy perception of phonological information, but it seems that this is only capitalised on at a representational level if it is introduced at an **early age**. Our review of the prior research has suggested that the role of auditory experience in the development of phonology may have been neglected. We want to know whether the early use of a cochlear implant supports the development of a phonologically structured lexicon and whether this is primarily due to the increased access to speech sounds afforded through the implant or due to early lexical development.

Chapter 3 – Cochlear Implants for Deaf Children

3.1 INTRODUCTION

The goal of cochlear implantation in children is to enable the development of spoken language (Summerfield & Marshall, 1995). In 1990, paediatric cochlear implantation began in the UK. At the beginning of the CI programme candidacy criteria was conservative. Children were only fitted with an implant if they had become deaf after the acquisition of spoken language. Furthermore, it was necessary to show that no functional benefit was gained from conventional acoustical hearing aids. Typically, the early candidates had to demonstrate that they possessed virtually no residual hearing (i.e. mean response to pure tone audiometry in the region of 120 dB HL). Since 1990 candidacy criteria has changed. Children born deaf have been fitted with implants, the age at which an implant is fitted has been reduced and there is a trend to fit implants even when participants have developed some spoken language using hearing aids. More recently, children are considered suitable candidates even if they have some useful residual hearing. Some centres fit implants to children who have severe-to-profound hearing loss or even severe hearing impairment (Blamey, Sarant, Paatsch, Barry, Bow, Wales, Wright, Psarros, Rattigan & Tooher, 2001). Despite the stated goal of cochlear implantation (to enable the development of spoken language), the large majority of studies have evaluated the benefits of cochlear implant by assessing speech perception. There has been a growing number of reports on speech production outcome, but relatively little research on actual language outcome.

The aim of this chapter is to uncover the nature of the relationship between hearing, speech perception and language. I want to assess the evidence that improved speech perception impacts on the spoken language development of children who have received cochlear implants. In order to do this I start with a brief overview of auditory capacity outcomes and consider the changes in candidacy criteria and technology that may impact on outcomes. The focus of the review of the speech perception studies is to assess factors that influence speech perception outcome. Then language development in CI users and the relationship between speech perception and language outcome are investigated. The final section of this chapter includes studies that provide a more functionally orientated picture of outcomes for children post cochlear implant fitting.

3.2 Auditory Capacity

Cochlear implantation is thought to be a good tool for enabling the development of spoken language of profoundly deaf children because it enhances auditory sensory capacity. A hearing **impairment** perspective has led some researchers in the audiology field to seek to establish functional equivalent hearing ages for children with cochlear implants. For example, Nakisa and his colleagues (Nakisa, Summerfield, Nakisa, McCormick, Archbold, Gibbin & O'Donogue, 2001) ask "Does a child implanted at age five who has used an implant for three years perform more like a normally hearing eight-year-old or a normally hearing three-year-old?" Others in the CI field talk in terms of '**hearing age**' counting only those months and years which the child has been fitted with an implant (Willis & Edwards, 1996). Pursuing these lines of enquiry might lead to a decontextualized understanding of hearing because it is not considered within the context of the whole developing child. Notwithstanding this conceptual issue, the question of age equivalent hearing levels and auditory capacity has been investigated in several studies. These studies suggest that auditory sensory capacity of totally deaf children who receive cochlear implants is enhanced by the fitting of a cochlear implant. Findings suggest that paediatric cochlear implant users have auditory capacity similar to less profoundly deaf children.

Boothroyd (1993) predicted the auditory capacity of CI users to be the same as a profoundly deaf child with a hearing loss of 100 dB HL. More recent studies show that this has improved so that some paediatric cochlear implant users **can** achieve levels similar to severely deaf children (Svirsky & Meyer, 1999; Nakisa et al, 2001). However, in the Nakisa study, the group mean on the auditory measure was 94dB HL which is on the severe-to-profound cusp. Furthermore, in this study the confidence intervals of the mean included the mean of 100 dB HL predicted earlier by Boothroyd.

3.3 Changing Benchmark Groups and Expectations

The original benchmark group against which CI users were compared was profoundly deaf children who make good use of their residual hearing with conventional hearing aids. This original benchmark group was termed "gold hearing aid users". This term not only reflects their unaided pure tone thresholds, (90 and 100 dB HL- ANSI classification system not UK) which means that they have the greatest amount of residual hearing within the classification of profound hearing loss, but it also makes reference to the ability to derive functional use of residual hearing with conventional hearing aids (Osberger, Robbins, Miyamoto, Berry, Myers, Kessler & Pope, 1991b). Children with greater degrees of deafness, measured by higher pure tone thresholds (101 – 110 dB HL), are typically termed "silver hearing aid users". Children who have unaided pure tone thresholds higher than 110 dB HL are termed "bronze hearing aid users". At the outset of paediatric cochlear implantation children with unaided pure tone thresholds above 110 dB HL were considered suitable candidates. According to Boothroyd (1993), children with this degree of hearing impairment would have **minimal auditory capacity** using hearing aids (see Chapter 1). Meaning that with hearing aids they would typically be able to perceive rhythm and intonation, but not many speech segments (i.e. vowels and consonants). If the fitting of a cochlear implant improves auditory capacity to the degree suggested by recent studies (i.e. to the same level as children with pure tone losses in the severe-to-profound region of around 94 dB HL), then the use of a cochlear implant should improve auditory capacity at least to the level of **considerable auditory capacity**, resulting in the perception of vowels and most consonants.

The results from the early studies of speech perception were presented using the terms 'gold' 'silver' and 'bronze' so in this review these terms of reference are maintained when describing those studies. However, the more recent studies no longer use these groups as benchmarks instead the unaided responses to pure tone audiometric assessment is provided. The more recent studies include children with profound and severe hearing impairment and are now also beginning to make comparisons with children who have no hearing impairment. These changes in comparison groups is a reflection of the advances in the cochlear implant field perhaps the most significant of these has been in the way that speech is encoded in the speech processor of the implant device.

In the early days of CI, the Nucleus processors were designed to extract information related to the only the fundamental frequency and the first and second formants of the vowel and only this limited set of features was presented to the electrodes. This feature extraction method was intuitively attractive being based on theoretical understanding of the most important acoustic cues for speech perception (see Chapter 1). However, better outcomes have been derived from the use of the SPEAK strategy, where sound is split into 20 frequency bands and stimulates the electrodes corresponding to the 6 bands where the greatest amplitude is present. Thus, the overall spectral pattern of the speech signal is preserved whereas in the feature extraction strategies of the early devices it was lost. This change appears to have been very significant in improving outcomes for cochlear implant users (Clark, 1998).

More recent advances have been introduced with the ACE strategy which allows much faster stimulation rates and uses all available electrodes.

The CIS strategy also has the benefit of a very fast rate of stimulation and with this strategy all electrodes can be stimulated simultaneously. Until very recently it has not been possible to include all these processing strategies in a single device, therefore intra-subject comparisons with all the various strategies has not been possible. This is because implant manufacturers develop speech processing strategies that are only compatible with their own device hardware. However, this is changing. The most recent version of the Cochlear speech processor can deliver SPEAK, CIS and ACE. So far, preliminary results from the UK (Parland, 2001) suggest that there are no significant differences in functional outcome relative to the speech processing strategies used. This may be because all of these strategies maintain the spectral shape of the speech signal (unlike the early feature extraction systems). Nevertheless, the changes in technology (including the development of fully implantable devices, brainstem implants, enhanced speech processing strategies) are likely to continue to have a role in determining outcome for cochlear implant users.

Improved speech perception is not likely to be the only factor that influences the development of spoken language. According to Locke (1997) the development of language will also be dependent on early communicative experiences (see Chapter 1). It is likely that type and amount of rehabilitation will impact on the child's communicative environment. This in turn will influence language development. In recognition of this many implant centres include rehabilitation focusing on psychosocial factors in children and their parents (see Bertram, 1996) and on developing communication between children and parents (see Lutman, Archbold, Gibbin, McCormick & O'Donoghue, 1996). However, the influence of these factors on language development are not easy to measure and it is even more difficult to pinpoint the way in which they may interact with auditory capacity to affect outcome.

3.4 Speech Perception

3.4.i Tests

There are many different tests of speech perception used in CI centres. Speech perception tests cover a range of perceptual abilities going from perception of stress and environmental sounds, through to perception of sentences, words and finally individual speech sounds (vowels and consonants). Tasks vary in response format. In **closed set tests** of words and sentences, a choice of possible correct responses is given. For example, the Early Speech Perception Test, developed by Moog and Geers (1990), has within it a test of monosyllabic identification. There are 24 trials in total and the child has to correctly select the word spoken by the tester, from a choice of 12 pictures. In **open set tests**, such as the Phonetically Balanced Kindergarten Test (PBK) (Haskins 1949), no choice is provided and the child has to repeat, sign or write down the word that was heard. Tests of open set speech perception are thought to most closely reflect real life communication. Therefore, in the cochlear implant field, it is desirable to show that cochlear implant benefits open set speech perception.

3.4.ii Speech Perception Outcomes

We have already seen that some recent studies show that auditory perceptual level is similar in cochlear implant users to children with severe hearing impairment although this cannot be said to be true for all cochlear implant users. The Imitative Test of the Perception of Speech Pattern Contrasts (IMSPAC Boothroyd, 1991b) is a speech perception test that relies on the child imitating non-sense syllables. The use of non-sense syllables rather than real words is a way of eliminating the confounding effects of language knowledge on speech perception tests. Boothroyd (1997) studied a group of deaf children with cochlear implants (n=50, mean CA 8.8 years) and deaf children with hearing aids (n=96, mean CA 9.5 years). The hearing aid users were separated into sub-groups based on their unaided pure tone thresholds. There were five groups; two groups of severely deaf children (70-79 dB HL and 80-89 dB HL) and three groups of profoundly deaf children (90-99 dB HL, 100-109 dB HL and 110-119 dB HL). The performance of the cochlear implant users was similar to the profoundly deaf children who had unaided pure tone thresholds in the 90-99 dB HL range. Although, there was a small group of cochlear implant users who had received intensive oral training (n=9) had similar performance to the whole group of severely deaf children (70-89 dB HL). The Boothroyd study (1997) shows that speech perception (assessed by imitation) is equivalent in the CI group to a group of severe-to-profoundly deaf children or what the early studies referred to as "gold hearing aid users". Similar findings have been reported by Geers and Brenner (1994), Somers (1991), Miyamoto, Kirk, Robbins, Todd and Riley, (1996) and Meyer, Svirsky, Kirk and Miyamoto (1998). Some recent studies now show that speech perception is in CI users is similar to children with severe hearing impairment. Blamey et al (2001) report that the average cochlear implant user with a hearing loss of 106 dB HL performs like an average hearing aid user with a hearing loss of about 78 dB HL (i.e. within the severe hearing impairment category). This study included children who had high levels of residual hearing **prior** to implant fitting (see introduction of this chapter) and therefore, the improved outcome may be a function of the existing levels of residual hearing prior to implant fitting. This finding shows that if we are able to make accurate conclusions about the outcomes for children fitted with implants then clear reporting of the audiological characteristics of the participants prior to cochlear implant fitting is essential. It is possible that the general improvement in speech perception outcomes over time is due to the changing audiological criteria of candidates that has taken place over the past ten years. As is common with all research with deaf children, all of the CI studies report wide variability in speech perception ability post cochlear implant fitting. We now go on to consider some of the factors that impact on outcome.

3.5 Factors That Impact on Speech Perception Outcome

3.5.i Communication Mode

In the study already described by Boothroyd (1991b) he found that the ability to accurately imitate nonsense syllables in the hearing aid group was strongly determined by degree of residual hearing. As residual hearing decreased, ability to imitate nonsense syllables also decreased. The determinants of outcome in the group with cochlear implants were duration of use with the implant and communication mode. Children in oral communication settings were better able to repeat nonsense syllables than children in total communication settings. However, communication mode was **not** significantly related to performance on the IMSPAC test in the hearing aid group. Boothroyd suggests that sensory capacity is not fixed by the pathology of the peripheral auditory system and the characteristics of the sensory aid, but that neural adaptation can increase the amount of sensory evidence extracted by higher level auditory systems (cortical and sub-cortical). This explanation does not fully account for the apparent contradictory findings regarding communication mode and speech perception in the two groups. If neural plasticity is influenced by auditory input then, assuming auditory experience is better in oral communication settings, communication mode should have also accounted for a significant amount of variance in the children using hearing aids.

Meyer, Svirsky, Kirk and Miyamoto (1998) also found that a CI group had speech perception abilities that were similar to a group of less profoundly deaf children, with unaided pure tone thresholds in the range of 90-100 dB HL. In their study, twenty-two of the CI group were in oral educational placements and twenty one were in total communication placements (TC). Whilst Meyer and his colleagues did not specifically assess the effect of communication mode on speech perception outcome they noted that children in oral programmes tended to have higher performance.

However, they say, "even if a test of the effect of communication mode .. proved to be significant... one would not ... generalize the result to infer that a particular mode of communication is superior to another". They argue this on the basis that in their hearing aid group, children educated in oral placements had more residual hearing than those in TC placements. Therefore, educational placement, and communication mode, is likely to be at least partially determined by the auditory capacity of the child.

This entirely appropriate caveat should be applied to other studies where a significant link between communication mode and speech perception outcome has been reported. Snik and his colleagues (Snik, Vermeulen, Geelen, Brokx & Broek, 1997) formulated an equivalent hearing loss value on the basis of speech perception performance. They analysed the speech perception abilities of a group of 16 CI users against an equivalent hearing loss value. They found a great deal of variability within the group. The best CI users were able to perform at an equivalent hearing loss value of 70-80 dB HL. In this study the best performers had become deaf during the acquisition of spoken language. The equivalent hearing loss values of the congenitally deaf participants, after two years of implant use, ranged from 85-105 dB HL. Snik and his colleagues found that communication mode together with age of onset of deafness, accounted for 64% of the variance in speech perception performance. If auditory capacity determines educational placement (and corresponding communication mode), then it is entirely feasible that the children who became deaf during the acquisition of spoken language had greater neural maturation at the time of the implant. This would therefore, be related to auditory capacity following fitting, making it more likely that they would be able to access the curriculum delivered using spoken language.

In a recent UK study Archbold and her colleagues (Archbold, Nikolopoulos, Tait, O'Donoghue, Lutman & Gregory, 2000) investigated longitudinal speech perception outcomes for 46 paediatric cochlear implant users at 36, 48 and 60 months post CI fitting. Twenty of these children used oral communication and 24 used signed communication. At each yearly interval children who used oral communication outperformed children using signed communication on all of the five speech perception tests administered. Age of implant fitting (which was a factor accounting for a significance degree of variance in performance) was controlled and the oral advantage remained significant for two of the five speech perception results. Children who changed placement from total communication to oral placements achieved outcomes that were the same as the children who had always attended an oral educational placement. Perhaps this paper comes closest to answering the question regarding the relative causal influence of communication mode on outcome for CI users. However, the authors conclude the paper by saying, “the question remains as to whether it is the oral approach that results in better performance, or whether children use oral approaches because of their better performance”.

3.5.ii Age of Onset of Deafness

There is physiological evidence, using auditory evoked potentials which suggests the age of onset and duration of deafness prior to implant fitting is related to the subsequent degree of maturation of the central auditory system (Ponton, Moore & Eggermont, 1999). However, the benefit of CI on speech perception is not limited to children who have become deaf after the acquisition of spoken language. A number of studies have shown that cochlear implantation does benefit speech perception in congenitally deaf children (Gantz, Tyler, Tye-Murray, Fryauf-Bertschy, 1993; Waltzman, Cohen & Shapiro, 1992; Waltzman, Cohen, Gomolin, Shapiro, Ozdamar & Hoffman, 1994). It might be expected, though, that participants who had some hearing in early infancy (pre-lingual) would benefit more from a cochlear implant due to early neural activation. Several studies have shown that age of onset of deafness does account for a significant amount of the variance in speech perception outcome (Staller, Dowell, Beiter & Brimacombe, 1991). However, other studies have found no significant differences in performance between congenitally deaf children and those who became deaf before 3 years of age (Tyler, Fryauf-Bertschy, Kelsay, Gantz, Woodworth & Parkinson, 1997; Miyamoto, Osberger, Robbins, Myres & Kessler, 1993).

These contradictory findings may be due to the **cause** of deafness in pre-lingually deaf children. In Waltzman et al's study (1994) there was no significant difference between a group of congenitally deaf children and children who had become deaf due to meningitis. In this study, all the children were fitted with implants before the age of five years. However, Nikolopoulos and his colleagues (Nikolopoulos, O'Donoghue, Robinson, Gibbin, Archbold & Mason, 1997) showed that children who had become deaf due to meningitis had significantly lower scores than congenitally deaf children on a test of listening performance. Their study included 85 deaf children with implants, 47 were post meningitic and 38 children were congenitally deaf. All the children were tested in the first year following implant fitting. The chronological age at the time of testing ranged from 1.9 years to 13.5 years (mean age of 5.4 years). The age at implantation was controlled. There was a significant difference in the duration of deafness prior to implant fitting. However, despite the fact that the congenitally deaf children had been deaf since birth they still outperformed the children who became deaf after meningitis and had shorter duration of deafness prior to fitting. Meningitis can result in wide spread damage to the central nervous system additionally, it often leads to ossification of the cochlea which may result in fewer electrodes being inserted during surgery. The number of active electrodes is not reported in Nikolopoulos's study and no measure of IQ was taken. The authors offer no explanation as to why the post meningitic group's performance was lower than the congenitally deaf group. However, this study does show that age of onset of deafness is not necessarily predictive of outcome post implant fitting and that cause of deafness may also be a factor.

3.5.iii Timing of Implant Fit

Many longitudinal studies have reported improvements in speech perception performance following fitting of a cochlear implant. Steven Staller and his colleagues (Staller, Dowell, Beiter & Brimacombe, 1991) report pre and post operative speech perception data collected from multiple CI centres in Australia. Their results showed that speech perception at all levels (from suprasegmental to open set word discrimination) improved significantly after 12 months of implant use. Their large sample included children who were congenitally deaf as well as those who had become deaf during the acquisition of spoken language. They found that the age at which children had become deaf significantly correlated with performance on the speech perception measures, acquisition of some language prior to the onset of deafness was associated with better outcome. In a longitudinal study of 34 prelingually deafened children, Fryauf-Bertschy and her colleagues (Fryauf-Berschy, Tyler, Kelsay, Gantz & Woodworth, 1997) showed that speech perception of stress, words (both closed and open set) and vowels improved significantly after the fitting of a cochlear implant. By the time children had been using their implants for 5 years, full time users were able to achieve 30% correct on the PBK open set test. After 36 months of implant use, participants fitted before the age of 5 years had significantly higher scores on the PBK test, than participants fitted after the age of 5 years. The difference between the groups was only evident after 3 years of device use. Other studies have also reported that the age at which the implant was fitted was a significantly related to performance on speech perception tasks (Waltzman, Cohen, Gomolin, Shapiro, Ozdamar & Hoffman, 1994; Tyler, Fryauf-Bertschy, Kelsay, Gantz, Woodworth & Parkinson, 1997; O'Donoghue, Nikolopoulos, Archbold & Tait, 1998; O'Donoghue, Nikolopoulos & Archbold, 2000; Archbold, Nikolopoulos, Tait, O'Donoghue, Lutman & Gregory, 2000). Waltzman and Cohen (1998) showed that children fitted before the age of 2 years, were able to achieve open set speech perception. Whilst they did not include a comparison group of children fitted after the age of 2 years, the authors compared the speech perception outcomes with those reported in their previous study (Waltzman, et al 1994). Their comparison showed that the children implanted before the age of 2 years achieved at least the same level of performance compared to children fitted between the ages of 2 and 5 years when tested at the same post operative interval. After five years of implant use, the children implanted before the age of 2 years had much better performance on an open set test of **sentence perception** than the children fitted after the age of 2 years. Although, on other speech perception measures of word perception, and phoneme perception, the advantage of early fitting seemed to erode with time.

So far, these studies support the hypothesis that early fitting with an implant benefits speech perception to a greater extent than later fitting. However, there are some indications in the literature that later fitting with an implant may still lead to a significant benefit in speech perception. Osberger and her colleagues (Osberger, Fisher, Zimmerman-Phillips, Geier & Barker, 1998) investigated the speech perception abilities in pre-lingually deafened children who had received their implants after the age of five years (mean age 9.2 years). Prior to cochlear implantation, their group of 30 deaf children were unable to show any open set speech perception (PBK, mean 0%). However, after only 6 months of device use, the participants' open set speech discrimination had improved significantly. The improvement was more dramatic for the sub-group of children using oral communication (post operative mean 27%), compared to the group using total communication (post operative mean 8%). This difference in improvement cannot be solely attributable to communication mode, however, since the children using oral communication had greater amount of residual hearing. This study does show, that the benefit of cochlear implantation is not totally limited by the age at which the implant is fitted.

Additional evidence to support this view comes from Gantz and his colleagues (Gantz, Tyler, Woodworth, Tye-Murray & Fryauf Bertschy, 1994). They found that children implanted up to the age of 13 years could obtain substantial speech perception information through a cochlear implant that was not obtained using conventional hearing aids. This was demonstrated by examining pre-operative performance with speech perception skills after two years of implant use. In addition, Snik and his colleagues (Snik, Vermeulen, Geelen, Brokx & van der Broek, 1997), showed that nine congenitally deaf participants, fitted with implants up to the age of 11 years (range 4 – 13 years), could achieve open set speech perception after three years of device use. Although this study did not include information on pre-operative performance, the longitudinal data showed that phoneme perception developed with cochlear implant use and this development was not totally dependent on the time at which the implant was fitted.

Summary – Speech Perception Outcomes in CI Children

One prominent advocate of the Deaf World, Harlan Lane (1992) is critical of the methodology of CI research. In particular he highlights the following shortfalls;

- the practice of pooling results from different implant centres,
- the combination of mixed populations of deaf children (in terms of age of onset of deafness, cause of deafness),
- the wide range of speech perception tests carried out by different experimenters
- the lack of longitudinal research
- the lack of experimental design to assess the influence of training and maturation on outcome.

Lane also says that the wide variability in outcome between CI users may be due to these factors. Some of Lane's criticisms are valid. Many studies have grouped participants whose chronological age varies widely, they combine children who were born deaf and those who have become deaf during the acquisition of spoken language. Also, the age at which the implant was fitted and the duration of use with the cochlear implant sometimes varies widely within groups. These methodological weaknesses make it difficult to draw firm conclusions. However, Lane's predictions about the cause of variability in outcome specifically age of onset of deafness and cause of deafness seem to have been confirmed by this review.

However, not all the studies presented here are subject to serious methodological weaknesses. It seems that cochlear implants benefit speech perception in children. Recent studies show that children fitted with cochlear implants perform at a similar level to children with severe-to-profound hearing impairment (i.e. around 90 – 95 dB HL) and outperform profoundly deaf children with comparable pure tone thresholds (i.e. around 120 dB HL PTA) who use conventional hearing aids. Some exceptional CI users have speech perception abilities that are similar to severely deaf hearing aid users. The longitudinal studies, showing pre and post operative performance also indicate significant improvement in speech perception once the implant has been fitted. There is a growing body of evidence to show that the age of fitting with an implant is an important determinant of outcome, but participants fitted with implants later also derive significant benefit from CI fitting. Some evidence suggests that the advantage of early fitting (< 5 years) may only be evidenced on the more difficult speech perception tests, and only noticeable after a number of years of device use. However, there is an indication that the advantage of very early CI fitting (< 2 years) on the harder tests of phoneme perception may erode over time. The age of onset of deafness is likely to be a factor affecting outcome, but children who have become deaf after meningitis generally have lower speech perception abilities than children born deaf. There is some evidence to suggest that communication mode determines outcome post implant fitting. However, it is likely that there is a reciprocal relationship between communication mode and auditory capacity, rendering this a very difficult question which has yet to be adequately addressed.

So, if these findings map onto language development, we should expect to find participants with cochlear implants have spoken language skills that are equivalent to children with severe-to-profound hearing impairment. If CI benefits spoken language development, then significant improvements in spoken language should be demonstrated after the fitting of a cochlear implant. If speech perception is a determinant of spoken language development, we would expect to find a relationship between speech perception and language. If speech perception does determine spoken language development, age of fitting, age of onset of deafness and cause of deafness should be determinants of language development.

3.6 Spoken Language Development

There have been a number of single case studies describing the language development of children with cochlear implants (Szagun, 1997; Willis & Edwards, 1996; Hasenstab & Tobey, 1991; Busby, Tong, Roberts, Altidis, Dettman, Blamey, Clark, Watson, Nicholls, Dowell & Rickards 1989; Dowel, Dawson, Dettman, Shepherd, Whitford, Seligman & Clark, 1991; Geers & Moog, 1991). All of these studies show improvement in language development over time. In order to address some of the questions outlined above, we will review only those papers with larger numbers of participants, where statistical analytical tools have been employed to investigate the significance of these improvements.

3.6.i Early Communicative Behaviour

Tait and Lutman (1994) assessed the pre-verbal communicative behaviour of children with cochlear implants. Their hypothesis was that cochlear implant fitting would reduce the need of a profoundly deaf child to observe the speaker in interaction. To test their hypothesis they compared the CI group (n=9, CA 3 years 4 months), with a group of "gold and silver hearing aid users" (n=9, CA 3 years 4 months) and a group of "bronze hearing aid users" (n=9, CA 3 years 1 month). The participants with implants had unaided pure tone thresholds in the same range as the "bronze hearing aid users". Participants using hearing aids all attended the same nursery school. The groups were well matched for length of hearing aid use, they had been using hearing aids for just over 1 year. The project started just after CI fitting for the CI group and at entrance to nursery school for the hearing aid users.

The experimenters recorded 5 minute interactions between the children and a known adult on 3 separate occasions over a 12 month period. They measured turn taking, autonomy of turn taking, eye contact and auditory awareness. The turn taking measures were categorised as being either silent with gestures or vocal with or without gestures. Auditory awareness was considered to be shown if a conversational turn was taken vocally, when the child had not had eye contact with the adult. The percentage of the opportunities to display these pragmatic functions was scored for each behavioural measure. The means showed that, overall, the CI group had similar communicative behaviour to the "silver/gold hearing aid users". These two groups displayed more vocal turn taking in contrast to the "bronze hearing aid users" who showed no vocal turn taking behaviour. The results were collapsed into two factors; a vocal auditory factor and an eye contact factor. At the start of the study, the CI group and "bronze hearing aid users" had similar scores on the vocal/auditory factor, but the CI group rapidly increased in this behaviour over time, whereas it decreased in the "bronze group". At six and twelve months the CI group had significantly higher means on the vocal auditory factor compared to both the "bronze hearing aid users" and the "silver/gold hearing aid users". The results from the eye contact factor were less discrete. All groups increased in eye contact over the course of the study. The "silver/gold" group had the highest levels of eye contact at the start of the study and this continued to be the case at the next two assessment intervals.

There was no significant difference between the CI group and the "bronze hearing aid users" on the use of auditory/verbal communicative behaviours at the start of the study. After a few months of implantation, the CI group rapidly became more auditory/vocal in their communicative behaviour, the "bronze group" showed no increase. These results show that the pre-verbal communicative behaviours of profoundly deaf children become more similar to the "silver/gold hearing aid users" after implant fitting. Eight of the nine participants in the CI group had early acquired hearing loss (mean onset 1 year 2 months), the hearing aid users were all congenitally deaf. However, the CI group's communicative behaviour at the start of the study was no different to the "bronze group". This shows that the early hearing experience of the CI group could not explain the rapid increase in auditory/verbal communicative behaviour during the course of the study, which is almost certainly due to the fitting of a cochlear implant. None of the children in the study were congenitally deaf. It would be interesting to see whether a rapid behaviour change in communication style after implant fit would also be characteristic of congenitally deaf children. If the development of a primarily auditory/verbal communicative style is related to the development of spoken language, then this should be reflected in the spoken language outcomes of deaf children with implants.

3.6.ii Vocabulary Development

A longitudinal study evaluating the acquisition of spoken vocabulary over three years was conducted by Geers and Moog (1994). They compared a group of CI participants (n=13) with a group of "bronze" hearing aid users (n=13) (HA) and a group of tactile aid users (n=13) (TA). A group of hearing aid users whose pure tone averages where between 90 and 100 dB HL (HA+) was also tested at the last data collection point only. The participants were matched for chronological age, which ranged from 2 years (mean 5 years 3 months) at the start of the study to 13 years (mean 8 years 3 months) at the end. Data was collected on four occasions over a three year period and collection started at the point when the CI group were fitted with their implants. By the last data collection point the CI group had been using their implants for three years. The authors used a battery of standardised tests normed on both deaf and hearing children.

Receptive Vocabulary

At the start of the study the three groups had equivalent receptive and expressive vocabulary age equivalent scores. The difference in age equivalent expressive and receptive vocabulary scores at the last data collection point, is not reported. However, figures in the paper show that the CI group's receptive vocabulary age (Peabody Picture Vocabulary Test, Dunn & Dunn, 1981) and expressive vocabulary age (Expressive One-Word Picture Vocabulary Test, Gardner, 1979) was slightly lower than the HA+ group, but greater than the HA and TA groups. All three groups made gains in receptive vocabulary over the course of the study, but there was no significant difference between the groups. The greatest gain was made by the CI group, for every chronological year their receptive vocabularies grew by .58 of a year. This gain is similar to what would be achieved by a group of deaf children with pure tone thresholds of 90 – 104 dB HL (Boothroyd, Geers & Moog, 1991).

Expressive Vocabulary

Differences in gain in expressive vocabulary were significant. The CI and TA groups made significantly more gain, by the end of the study, than the "bronze hearing aid users". In fact, the CI group had a slope of 1.1, showing that expressive vocabulary was growing at a slightly faster rate than chronological age, which is the type of gain that would be expected of hearing children.

There is quite a large discrepancy between gain in receptive and expressive vocabulary, with higher gains reported on the expressive test for all groups. Furthermore, the age equivalent scores on the expressive vocabulary test were higher than the corresponding score on the receptive language test. This finding does not concur with normal language development where receptive skills underpin expressive skills. This is probably due to a difference in the tests used. It suggests that the expressive test is an easier test than the receptive test. Therefore, the conclusions made about the rate of expressive language skills in CI participants should be interpreted with some caution.

Dawson and his colleagues (Dawson, Blamey, Dettman, Barker & Clark, 1995) used a pre-post operative design to investigate the rate of change in receptive vocabulary using the Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981) in a CI group. They also tested speech perception, using a closed set test of word recognition (Picture Vocabulary Test, Plant, 1984), but they do not report longitudinal speech perception data. Their study included 32 "patients" who had implants, which included children, adolescents and adults. The age at implantation varied widely from 2 years 6 months to 20 years 1 month. The study started at the pre-implant phase, so the chronological age at the time of the first data collection point is roughly equivalent to the age at implantation. The mean pure tone thresholds of the group, prior to implant fitting was 115 dB HL. There was a mixture of congenitally deaf, pre-lingually deaf and post-lingually deaf participants. The speech processing strategy used by the participants was also different and changed for some participants during the study. One problem with this study is the variability between participants.

The pre-operative rate of vocabulary quotient was .35 (n=14), following 6 months of CI use it rose to 1.1. They found that the rate of growth in vocabulary development was significantly higher following the fitting of a cochlear implant at all of the test intervals (ranging from 6 months post implant to 42 months). In order to assess the determinants of vocabulary growth they performed a forward stepwise regression analysis. The dependent variable was the "overall rate of change on the PPVT which was available for 32 participants at "their most recent assessment". They included 6 steps; duration of implant use, duration of profound deafness, age at implantation, age at onset of profound deafness, speech perception and communication mode. The results indicated that **none** of these variables was a significant predictor of receptive vocabulary development, post implant fitting. Separate correlations showed that age of implant fit was related to the age equivalent score on the PPVT ($r = 0.4$, $p < .05$), but not with the rate of change. Speech perception was not related to vocabulary development, but it was strongly related to age of implant fit ($r = -0.6$, $p < .001$).

Dawson's findings suggest that speech perception does not determine spoken language development. The age of implant fitting might be related to the level of receptive vocabulary, but does not appear to be a strong determinant of vocabulary growth. However, this study did not use a longitudinal design to assess the relationship between speech perception and spoken language development so conclusions based on these findings should be tentative. Furthermore, the wide variability between participants, especially in chronological age may have masked a relationship between speech perception and spoken language development.

A more recent study from the Australian group (Blamey, Sarant, Paatsch, Barry, Bow, Wales, Wright, Psarros, Rattigan & Tooher, 2001) investigated the relationships between hearing, language and speech production. They investigated these skills in 40 deaf children using hearing aids (unaided PTA range 40 dB HL – 103 dB HL0) and 47 children using cochlear implants (unaided PTA range 77 dB HL – 125 dB HL). The age of the participants ranged from four years to 12 years old. All the children experienced hearing loss before the age of five years. Two measures of receptive language were administered, the PPVT and the Clinical Evaluation of Language Fundamentals – CELF (Semal, Wiig & Secord, 1992, 1995). Using regression analyses of language measures as a function of age, they found that rates of improvement on the PPVT measure was equivalent for the hearing aid users (.65) and cochlear implant users (.63). The deaf children in this study were learning receptive vocabulary at about two thirds the rate of the normal rate (which would be 1). This analysis is based on hearing normative data where language development is assumed to be linear with age so that in every twelve months an equivalent amount of vocabulary is acquired, yielding a quotient of 1. Slightly lower rates were reported for the CELF scores, .59 (hearing aid users) and .56 (cochlear implant users). There was a very high correlation between the two language measures. These findings suggest that the fitting of a cochlear implant does not influence rate of language development in deaf children. Somewhat consistent with this finding is that fact that degree of residual hearing (measured by the PTA) did not appear to be causal in the rate of language development for either group. Members of the same research group had previously reported that language knowledge had an effect on speech perception (Sarant, Blamey, Cowan & Clark, 1997). Their theoretical interest may have influenced the way they investigated the causal connections between the language and auditory perceptual skills. A range of speech perception measures were highly correlated with language development, but the authors did not report on the degree to which speech perception accounted for variance in language skills. According to the regression model used, the authors suggest that most of the children in the study would have the language of a seven to eight year old child by the time they were twelve years of age and entering secondary school.

3.6.iii Receptive Language Development

There have been three reports, from the Indiana University School of Medicine, on the development of spoken language using the Reynell Developmental Language Scales (RDLS) (Reynell, 1985). The Reynell tests receptive and expressive language. It is developmentally organised and suitable for use with hearing children from the age of about 12 months to 7 years.

Miyamoto, Svirsky and Robbins (1997) report the results from the expressive sub-test of the RDLS. The CI group (n=23) were tested before implant fit, 6 months and 12 months after implant fit. The average age at the time of implant fit was 4 years 2 months. This was also the average age at the start of the study. The CI group was compared to a group of 89 profoundly deaf “bronze hearing aid users” (CA 4 years 2 months). The hearing aid users were seen once at the beginning of the study. The RDLS was administered in the subject’s own communication mode. Raw scores on the RDLS were converted into age equivalent scores and age equivalent scores divided by chronological age to yield a language quotient. The results showed that all the deaf children had expressive language that was well below hearing children. At the start of the study, the language quotients for all the deaf children was equivalent to 5 months of language growth over a one year period (slope = 0.42). The authors assumed that the rate of language growth would be constant over time. They predicted, therefore, that the deaf children (without cochlear implants) would continue to develop language at the rate of 5 months of progress in one year. The mean language age of the CI group is shown on a graph. The approximate mean language ages are given below;

	Pre Implant	**6 months post**	**12 months post**
CI Group	27 months	33 months	40 months
Bronze Group	27 months	**30 months*	**32 months*

** predicted scores*

Despite having unequal sample sizes in each group, a repeated measures ANOVA was computed using the predicted and actual scores at the 6 month and 12 month interval. There was a significant interaction effect, the difference in predicted and actual expressive language ages (i.e. <u>predicted</u> scores with continued hearing aid use and <u>actual</u> scores after the fitting of an implant) was significant at the 12 month interval. Over the course of the study, the rate of expressive language in the CI group was in line with their chronological age, they made about 12 months language gain in the 12 months following the implant fit. However, the CI group remained significantly delayed, compared to hearing normative data. The *predicted* gain in language for the "bronze hearing aid users" was much slower, being about half that of the CI group. This finding is similar to the group's first report (McConkey Robbins, Osberger, Miyamoto & Kessler, 1995), where there was no seen hearing aid comparison group.

In their third study, Svirsky, Robbins, Kirk, Pisoni and Miyamoto (2000) tested 23 children with implants (CA 4 years 5 months). The methodology for this later study is similar to their earlier work, although no hearing aid users were tested. In addition to the Reynell, the PBK speech perception test was administered at the 2 year post implant interval to 18 of the 23 children. The language quotients of the CI group was compared to predicted growth in language in hearing aid users. The results showed that prior to implant fitting there was no difference between the CI group and the normative data from "bronze hearing aid users". After implant fitting, the difference between the CI group and the predicted language ages from the hearing aid users was significant after 12 and 18 months of implant use. In line with their previous findings, Svirsky et al report that language gain in the CI group was faster than that which would be expected if the children had continued to use conventional hearing aids. The authors suggest that speech perception is related to language outcome and that communication mode is a predictor of speech perception. The data used to support these suggestions warrants further discussion.

Of the eighteen CI participants who were administered the PBK test, 7 were in oral placements and 11 were in TC placements. The scores from the PBK test are presented in a graph, the mean is not provided. The range of scores on the PBK test for the oral sub-group extended from around 38% to 90% of phonemes correct. The range in the TC sub-group extended from 0% to 60% correct. Overall, the TC group had lower performance on the PBK test than the oral group. The language quotients of the two sub-groups (TC and oral) is provided in a graph. The range of language quotients in the TC group extended from just below .6

to just below .9. The range in the oral group extended from just above .3 to .9. However, the language quotient of .9, in the oral group, appears to be an extreme score, most of the quotients in the oral group were between .5 and .6. The actual mean language quotients are not provided in the paper, I have summarised the information below;

	Oral	TC
PBK Range of % of Phonemes Correct	38 – 90	0 – 60
Language Quotients Range	.3 - .9 (with outliers) .5 - .6 (no outliers)	.6 - .9

The graph presented in the paper shows that the overall language quotient in the TC group was **higher** than that of the oral group. Speech perception in the TC group was lower than that of the oral group.

At 2 years post implant fit, the correlation between language quotient and the PBK speech perception test was strong for the sub-group of 7 participants who were educated in oral placements (r = .92), but not for the 11 participants in TC placements (r = .46). It is possible that the strong correlation in the small group of oral participants was heavily influenced by an extreme score (this subject achieved 90% correct on the PBK test and had a language quotient of .9). There were several participants in the oral group who achieved high scores on the PBK test (1 at 80%, 3 at 60%) who had language quotients between .5 and .6. These language quotients are **lower** than three children in the TC group who had language quotients of .7, but who had PBK results of around 30%. However, despite this, the authors conclude by saying that the large amount of variability in language development in CI participants is related to speech perception. "Children who perceive spoken words better are much more likely to approximate normal development of oral language". This statement implies that the oral communicators have more normal language development due to better speech perception than the TC communicators. The data on which this claim is made, does not support this conclusion.

Summary – Spoken Language Development

Overall, the findings suggest that cochlear implant significantly improves the **rate** of language development, which becomes evident after about 1 year of device use. However, there are some inconsistencies in the data with some studies showing that the rate of language development after an implant fit is in line with the rate of language development in hearing children (i.e. the Indiana Group) and other studies suggesting that rates of language development remain slow compared to hearing norms (i.e. Blamey et al, 2001). Post implant language levels are similar to "gold hearing aid users", but still significantly delayed when compared to hearing children. The findings from the Indiana group show that the gap in receptive language between profoundly deaf hearing aid users and hearing children gets bigger with time. However, it seems that the fitting of a cochlear implant prevents this continuing divergence. The obvious prediction from these findings is that early fitting of an implant would reduce the initial size of the language gap between deaf and hearing children and would prevent its increase. The two studies which examined the concurrent relationship between speech perception and language development have not provided evidence of a causal relationship between speech perception and language. The Blamey study showed that degree of residual hearing was not related to language development and the correlation reported between these measures was biased towards language level being causally related to performance on tasks of speech perception. Age of implant fit may be a determinant of language level, but it seems much more strongly related to speech perception than language development.

3.7 Functional Outcomes for CI Users

There are a number of assessments that provide useful descriptive data using a classification system that relates to functional skills. Categories of Auditory Performance is one such rating scale that was devised in the UK (Archbold, Lutman & Marshall, 1995) and is routinely used in a number of CI centres. There are eight categories in total ranging from "no awareness of environmental sound" through to "discrimination of some speech sounds without lipreading" and the final category is "can use the telephone with a known speaker". Archbold and her colleagues (Archbold et al, 2000) report that after three years of device use participants' abilities ranged between category 5, able to "understand common phrases without lip-reading" and category 6 able to "understand conversation without lip-reading". Children using oral communication tended to achieve category six, the median category for the signing group was 5. Interestingly, there were no significant changes to these categories when the participants were tested at four years post implant fit and at five years post implant fit. So, if these findings are representative of the UK CI population then it seems that after five years of device use profoundly deaf children are able to rely on 'hearing' alone to maintain a level of functional conversation ability.

Another category based assessment that describes the functional level of speech production which is widely used in CI centres is the Speech Intelligibility Rating Scale (SIR). This assessment is used to monitor the developing intelligibility of speech and voice and consists of six categories. They range from "no recognisable words in spoken language" to "intelligible to all listeners". Results reported from the Nottingham CI Team show that after three years of device use the median category achieved by signing group was 2, 'speech is unintelligible but child is using some lip patterns and attempts some words'. The median result for the oral group was 3, 'speech is unintelligible, but experienced listeners can follow a known topic via lip reading and context cues'. After five years of device use this had improved to category 3 for the signing group and category 4 for the oral group, 'speech is intelligible to all listeners who are listening and watching'. Results presented from the Great Ormond Street Cochlear Implant Centre (McKenzie, 2002) show that after five years of device use 50% of paediatric cochlear implant users develop intelligible speech (SIR categories 4, 5 and 6). If these findings are representative of the CI population then we can conclude that the improvements to speech intelligibility are variable following CI. Some children are able to achieve speech that is fully intelligible and others are unintelligible. Variability may be related to communication mode.

These descriptive outcome measures give a broad brush description of CI outcome. Such measures are currently being employed in the UK's Evaluation of the National Cochlear Implant Programme being conducted at the Institute of Hearing Research in Nottingham. The Nottingham study is using these measures together with outcomes from national educational assessment to examine the cost-effectiveness of cochlear implant fitting. So far, the authors have shown that children implanted early with cochlear implants are more likely to be educated in mainstream schools (Summerfield, Marshall & Archbold, 1997). This is especially the case if children receive cochlear implants at a young age (Archbold, Nikolopoulos, O'Donoghue & Lutman, 1998). It is likely that parental expectations may well influence educational choice and it is not yet clear whether educational outcomes for children in the UK are significantly enhanced by the fitting of a cochlear implant.

If cochlear implant fitting does improve language outcomes for deaf children then this should have a direct impact on educational attainment and in particular reading. This was the hypothesis of Tomblin, Spencer and Gantz (2000) who investigated the reading abilities of 30 paediatric cochlear implant users (mean age 12.8 years). The ages of the participants ranged from 8.5 years to 18.4 years. and the average length of device use ranged between 36 months and 132 months. They used a paragraph comprehension test and compared the CI groups reading attainment at two time intervals. The results showed that at T1 the average grade reading comprehension level was 3.53 and at T2 (approximately 12 months later) the average level was 5.62. There were no comparison groups tested, but the authors use the dramatic rise in reading comprehension results as evidence of the efficacy of cochlear implants on reading outcome. The improvement in reading ability between T1 and T2 is indeed dramatic, however, the wide range of ages and implant factors of the participants should constrain the attribution of this change in reading comprehension to the use of a cochlear implant. Recent reports on reading attainment presented by Boothroyd (2001) indicate that whilst speech perception outcomes may have improved in recent years, the reading attainment of deaf children using cochlear implants remains similar to that of profoundly deaf children using hearing aids.

Summary

Functional outcomes following cochlear implant fitting need to be reported so that the cost effectiveness of the procedure can be established. The decisions about cost effectiveness will be strongly related to educational attainment because this is seen as having a direct bearing on issues such as employment status and mental health. So far there is very little evidence to show that the improved hearing, speech perception and language skills derived through the use of a cochlear implant impacts on educational attainment. The results from the MRC study will provide a description of the educational attainments of the UK CI population. This information can then be compared to groups of deaf children using hearing aids to yield a broad understanding of the benefits of cochlear implant fitting. However, a study of this breadth and necessary shallow depth, cannot extend our understanding of why cochlear implant fitting does (or does not) enhance educational outcomes for deaf children.

3.8 CONCLUSION

The main aim of this chapter has been to uncover the nature of the relationship between the variables of hearing, speech perception and language. Attempting to determine the causal relationships between inter-related constructs is difficult and complicated by the fact that participants in the studies usually vary widely on a number of important factors such as age, age of onset of hearing loss, duration of CI use etc. Cochlear implant fitting enhances speech perception performance so that it is at the same level as deaf children who have greater residual hearing and are able to make good use of conventional hearing aids. Factors such as the age of fitting, the cause of deafness and the age of deafness are all related to speech perception outcome. Studies of language development indicate that cochlear implant fitting improves the rate of spoken language development. It seems that language levels achieved after 12 or 18 months of device use are equivalent to the benchmark group of "gold hearing aid users" or the severe-to-profound hearing impairment group (i.e. around 90 – 95 dB HL).

This finding of equivalence in speech perception and language outcome suggests that speech perception is related to the development of spoken language after cochlear implant fitting. However, so far there is no direct evidence of a causal relationship between speech perception and language development. The language studies in the CI field in particular seem to have significant methodological limitations which may have limited the degree to which they could assess the relationship between speech perception and language development. We suggested that if speech perception was causally related to language development then factors such as age of onset of deafness and timing of the implant fit would also be related to language development in CI users. Although there is no direct evidence of this, the results from the language studies suggest that the early fitting of a cochlear implant will attenuate the delay in language development relative to hearing peers. The best available evidence which shows that cochlear implant fitting impacts on the development of language comes from the study of Tait and Lutman (1994) which investigated the early communicative behaviours of deaf children. If the implant changes communicative behaviour and as a result of this change hearing carers find it easier to engage their children in interaction this would lead to improvements in social interaction and subsequent language development. However, according to Locke's theory (1997) this enhancement may take place too late to ensure the rapid development of the lexicon which he claims is required to activate the analytic and computation mechanism. This mechanism is fundamental to the development of grammar although (see Chapter 1). Cochlear implant fitting might appear to attenuate the gap between deaf children and hearing children's language development when measured using surface level descriptions and global language assessments. However, the prediction from Locke's theory is that detailed language assessments which probed knowledge of syntactic, morphological and phonological structure would reveal larger deficits in the underlying language knowledge of CI users.

None of the studies reported here were able to show that they had matched hearing aid users and cochlear implant users on factors such as specialist longitudinal assessment, rehabilitation or family factors. Although an increasing number of studies are investigating the relative contribution of these factors by entering variables such as the number of medical consultations post implant fitting into a regression analysis (i.e. Blamey et al, 2001). The assessment protocol prior to cochlear implant fitting and rehabilitative services following implant fit mean that CI participants have different quality and quantity of intervention than children using hearing aids. Therefore, when the benefit of cochlear implant is inferred, it should be recognised that this benefit does not **only** reflect enhanced auditory input to the cochlear nerve. It is probably impossible to find a group of hearing aid users who have received a comparable degree of assessment and rehabilitation as a CI group. Therefore, our understanding of the degree to which the enhanced auditory capacity gained through an implant influences language outcome will always be limited.

Chapter 4 – CI Participants in The Study

4.1 INTRODUCTION

This thesis sets out to answer several research questions concerning the possible benefits of cochlear implant fitting on the phonological awareness skills of young deaf children. We are also interested in understanding the impact of the timing of cochlear implant fitting on phonological awareness. Within the thesis the nature of the relationships between speech perception and phonological awareness (PA) and vocabulary development are explored. In addition, the possible causal role that phonological awareness has on the word recognition skills of deaf children with cochlear implants is investigated. The main aim of this chapter is to introduce the CI participants. This is done descriptively in Part 1 of the chapter and analytically (with research questions) in Part 2. The chapter's two parts are;

Part 1	The Methodology – Description of the study
Part 2	Early vs Late CI – Analysis of impact of timing of CI fitting

In Part 1 the overall study design is outlined, the constraints under which the study was carried out are described, the children fitted with cochlear implants who took part are presented and the published tests that were administered as part of the study are provided. The experimental tests of phonological awareness that were designed by the author will be fully described in Chapter 5.

One of the supplementary research questions of the thesis is to assess the relative impact of the timing of the cochlear implant fitting on phonological awareness. As we have seen in Chapter 3, age of implant fitting emerges as a strong predictor of subsequent outcome following cochlear implantation, children fitted with an implant early have better outcomes in speech perception and language skills. We predict that early implant fitting will also benefit phonological awareness. However, in order to ensure that any difference between the two groups is due to the difference in the timing of the implant fit, other potentially significant differences (i.e. that may have an influence on outcomes) must be identified (such as age of diagnosis, degree of residual hearing pre-CI and functional language development pre-CI). In Part 1 of this chapter, I will describe the similarities and differences prior to the fitting of an implant between the two sub groups of CI children that were tested (i.e. those fitted early and those fitted later). The characteristics of the participants in the two groups will also be presented.

The literature reviewed in Chapter 3 shows that early fitting of a cochlear implant (before the age of 5) leads to better outcome on tasks of speech perception (e.g. Fryauf-Bertschy, et al, 1997). This is assumed to be because of greater plasticity of the auditory pathways and cortex at the time of the implant (Robinson, 1998; Ponton, Moore & Eggermont, 1999). The hypothesis within the CI research field is that increased auditory capacity has a positive influence on the **rate** of language development. We have seen in Chapter 3 some evidence to support the view that implant fitting enhances rate of spoken language development (McConkey Robbins, et al, 1995; Miyamoto et al, 1997; Geers & Moog, 1994). The second part of this chapter investigates the impact of the timing of cochlear implant fitting on speech perception and spoken language development. Then the longitudinal relationship between speech perception and subsequent language development is explored for the whole CI group studied in this thesis.

PART I

4.2 METHOD

The study has a prospective, short-term longitudinal design. Figure 4.1 shows the overall design of the study.

Figure 4.1 Study Design

Research Question	Group	Measures	Chapter/s
What is the developmental trajectory of phonological awareness in deaf children with cochlear implants?	CI Group n =19	Experimental tests of phonological awareness of 3 linguistic units; o syllable o rhyme o phoneme Two data collection points; o T1 – October 1999 o T2 – October 2000	Chapter 5
Is there an effect of timing of the implant fit on PA? a) development & performance b) the source of phonological knowledge	CI Group sub divided into two groups; Early (CIE)– n=9 Late (CIL) – n=10	a) Experimental PA tasks (S,R,PH) at T1 & T2 b) Sub-set of trials from experimental PA tasks – non orthographically congruent trials (0-) tests of true phonological sensitivity	Chapter 5 Chapter 7
Is there a benefit of CI on PA? a) relative to deaf children using hearing aids b) relative to hearing children	CI Group compared to two groups of deaf children using hearing aids; profoundly deaf (PHA) n=11 severley deaf (SHA) n=9 hearing children matched for reading level (RL) n=19 hearing children matched for chronological age (CA) n=19	Experimental PA tasks (S,R,PH) at T1 Sub-set of trials from experimental PA tasks – orthographically incongruent trials (0-) tests of true phonological sensitivity	Chapter 6 Chapter 7
What are the determinants of PA?	CI Group Group of hearing children with history of language delay (SLI)	Experimental PA tasks (S,R,PH), including 0- trials at T2 Experimental PA tasks (S,R,PH), including 0- trials at T1 Background Measures; non-verbal IQ, receptive vocabulary, speech perception, short term memory	Chapter 8
Does PA support word recognition in deaf children with CI? a) What is the specificity of the relationship?	CI Group Comparison of advanced (GR) and less advanced (PR) deaf readers based on word recognition ability (mixed group, PHA/SHA/CI)	Experimental PA measures (0-) only at T1 and word recognition at T2. Background measures (as above)	Chapter 9

4.2.i Participants

Clinical CI Candidacy Criteria

Decisions about candidacy for cochlear implant are made by clinicians in the CI centres. Clinical decisions are based on the assessment findings relating to areas of child development, family expectations and audiological criteria. At the time when the participants in the study were candidates for cochlear implantation, it was desirable to show that they were not gaining any useful input from conventional hearing aids. Children who were benefiting from hearing aids would most likely, not be considered as suitable candidates.

Identification of the Sample of the CI Population

This study was originally planned in collaboration with the cochlear implant team at GOSH. Therefore, in the first instance links were established with the clinicians at the GOSH CI centre. During the preliminary stages of the study the experimenter also visited two other major implant centres in the UK (Nottingham and Manchester). However, the perceived potential significance of this prospective study meant that the clinical director of the CI team at GOSH was very keen to restrict the involvement of the other major implant centres. Therefore, even though there was an interest from the other centres, their possible involvement could not be taken further. This meant that the clinical population from which the sample was drawn was somewhat restricted in size. At the start of the study in 1998 cochlear implants had been fitted to approximately 1600 children in the UK (based on predictions by Summerfield & Marshall, 1995). When this project began in October 1998, 116 children had been fitted at GOSH. However, considerably fewer children than this fitted our inclusion criteria.

Inclusion Criteria

In order to minimise the heterogeneity within the group the following criteria for entry to the study was imposed on the CI sample at GOSH.

- congenital profound deafness
- no general learning difficulties
- English the first and only oral language
- full time users of the implant
- using the implant for at least 3 years

The planned comparison of early versus late fitting with a cochlear implant meant that children were suitable if they were fitted under the age of 3.6 years and between the ages of 5 and 7 years.

In total, 30 children met this criteria. Given this relatively small number we sought and gained agreement to involve one other CI centre. The centre chosen by the clinical director of the GOSH CI programme was the South of England Cochlear Implant Centre (SOECIC). A further six children at SOECIC met criteria for entry to the study. This meant that between the two centres a total of 36 children met the entry criteria. All these children were invited to participate in the study by sending written information and consent forms to the parents/carers.

Internal and External Constraints

The internal (i.e. the study's own criteria) and external (i.e. the GOSH/ICH constraints) meant that even if parental consent was granted for all the eligible children the group sizes would have been low. However, we had reason to believe that there would be a very high participation rate given the emphasis placed on participation in research by the team at GOSH. At GOSH all parents of children fitted with an implant are made aware of the ongoing research programmes at the centre and there is an emphasis on research participation from the very beginning. All parents are asked to sign a consent form to state that they are aware of the important role that research plays in the development of the field of cochlear implants and that they are disposed to allow their child to participate in research at the centre. In addition to the constraint regarding the involvement of other centres, the GOSH clinicians also gave advice regarding the location of testing, the total number and length of sessions. We were restricted to four sessions that were to last no longer than 40 minutes in duration.

Study Sample

Positive consent was received from 21 carers, representing nearly 60% of the total sample. Whilst this number was lower than anticipated it still represented a relatively high proportion of the children who fulfilled the study criteria. Further contact in order to increase the sample size was felt to be unethical (see Lynch, Glaser, Prior & Inwood, 1999). One participant was excluded because results from the British Ability Scales, Matrices (Elliott, 1996), indicated that non-verbal reasoning was well below the normal range. Testing of another participant was delayed because he was too young to participate in testing at T1. He was subsequently excluded from the study because GOSH reported that he was no longer a full time user of the implant.

Nineteen children fitted with cochlear implants fulfilled selection criteria and participated in the study at T1. Seventeen of the participants were in the GOSH CI programme and two were in the SOECIC CI programme. One child from the CIL group was withdrawn from the study after T1, leaving eighteen participants in total at T2.

Early and Late Groups

Nine children were fitted with their implant after the age of 2 years and before the age of 3 years 6 months, these children are the Early Group (CIE). Six of these nine children were boys. Ten children were fitted after the age of 5 years and before the age of 7 years, these are the Late Group (CIL). Four of these children were boys. All the participants were fitted with the Nucleus, Esprit 22 cochlear implant and were using the SPEAK encoder strategy.

The decision to refer for cochlear implant fitting will ultimately rest with local audiological services which may in turn be influenced by a range of factors. For example, knowledge about CI candidacy criteria, attitude towards cochlear implants, local budgetary constraints may influence the decision to refer and the timing of the referral. Parents may also influence the referral, especially the timing of referral. All of the children in the study who were fitted with their implants at GOSH (n=18) followed the same pre-implant assessment process and there was no significant discrepancy between the time the referral was received and the time of the decision to implant between the early group and the late group. It is the opinion of the clinical programme director at GOSH that the reason for relatively delayed referrals in the late group was due to referral policies and procedures at the local level rather than due to systematic differences between the children or families in the early and late groups. It is not possible to provide equivocal answers as to why some of these children were **referred** for cochlear implant later than others. However, it is possible and desirable to look at pre-implant factors such as degree of hearing loss pre implant and age of diagnosis in order to ascertain the possible differences between the two groups prior to CI. This information is provided in table 4.1.

table 4.1 CI Groups (Early and Late) Pre-CI

Intls.	Ed.Pl	Comm. Method	Aetiology	Age of Diagnosis	PTA pre-implant	Date of CI	Elect-rode No. T1	Deaf parent or sibling
CIE Group								
af	U	O	unknown	.67	-	.94	19	
bg	MSS	O	genetic (AR)	.25	120	6.94	18	deaf sibling
bc	U	O	unknown	.83	120	6.95	15	
tf	U	TC	unknown	.67	125	02.95	17	
ea	U	O	Mondeni	.50	115	10.95	17	
ah	MSS	O	unknown	.92	115	5.95	19	
aj	U	TC	unknown	1.50	100	.93	16	
rm	MSS	O	unknown	.58	117.5	10.96	18	
mp	SS	TC	CMV	.92	120	08.94	17	
CIL Group								
mm	SS	TC	genetic (AR)	.67	112.5	12.93	19	deaf sibling
cb	U	TC	unknown	1.50	117.5	1.97	20	
cc	U	O	rubella	.42	97.5	10.96	19	
dj	U	TC	unknown	2.00	122.5	6.96	17	
lp	U	O	unknown	.67	110.0	09.97	20	
sg	MSS	O	unknown	1.00	117.5	12.96	18	
hm	U	O	genetic	.33	117.5	5.96	18	deaf parents
jm	U	TC	genetic (AR)	1.50	102.5	7.96	17	deaf sibling
sa	MSS	O	unknown	.25	117.5	5.96	17	
cl	U	TC	genetic	.75	112.5	04.97	20	deaf sibling

Ed.P = Educational Placement at T1 (MSS – mainstream school, U = unit attached to mainstream school, SS – special school for deaf children) at October 1998

Comm. Method = Communication Method (O= oral, TC = Total Communication) at October 1998

AR = autosomal recessive

(PTA is the threshold response to pure tones presented at 500Hz, 1KHz, 2KHz and 4KHz in the better ear)

Inspection of the data shows that there is a high degree of overlap in the age at which children were diagnosed as being deaf. Children in the late group do not appear to have been diagnosed later than children in the early group. The difference between the two groups in the age of diagnosis was not significant (p =. 51). The degree of deafness prior to implant fitting seems to be slightly higher in the early group, however, the younger age of the children at the time of the behavioural test may have influenced responses. In fact, there is no significant difference between the two groups in terms of the pre-CI degree of hearing impairment measured by pure tone audiometry ($p = .30$). All the children are profoundly deaf according to UK classification. There are more children whose deafness is genetically inherited in the late group and therefore, a higher number of these children had deaf siblings or deaf parents. It is unclear from the CI literature whether having a deaf sibling or deaf parents would influence outcome following a cochlear implant, however in general the outcome for deaf children whose parents are deaf is favourable compared to deaf children of hearing parents (see Chapter 1). However, if having deaf siblings/parents has a positive influence on outcome (including the development of a phonological lexicon based on spoken rather than signed language) then children fitted later would have an advantage over those fitted earlier and this is contrary to the predictions made in this thesis.

Language Development Prior to CI Fitting

One of the criteria for CI candidacy is that the child is not developing spoken language using conventional hearing aids. It is possible that the children in the early and late groups differed in the degree to which they were developing spoken language using conventional hearing aids. One reason for the relatively late referral of children in the late group could be that they were making reasonable progress in the development of spoken language using hearing aids. In order to investigate this possibility, data about the pre implant language development was collected from clinical files at the implant centres.

The pre-implant level of spoken receptive language is presented in table 4.2. These data were collected by the specialist speech and language therapists at the centres who used a combination of formal and informal assessment methods to derive an overall receptive language age for each child. The tests are administered using oral language alone, so the language levels derived indicate receptive **spoken** language ability. The chronological age (in months) at the time of the language assessments is given in the first column.

table 4.2. Receptive Spoken Language – Pre Implant

	CA pre CI in months	Language Age Pre CI in months
CIE Group		
af		-
bg	29	18
bc	38	18
tf	35	9
ea	35	9
ah	38	9
aj	32	9
rm	31	9
mp	37	9
Mean CA	**34.37**	
CIL Group		
mm	72	18
cb	59	9
cc	75	18
dj	72	18
lp	67	30
sg	77	51
hm	84	30
jm	71	18
sa	71	18
cl	72	9
Mean CA	**72**	

The children in the late group were considerably older at the pre-implant stage when these assessments were carried out which hampers comparison to some degree. However, there are some patterns of similarity between the two groups and some clear individual differences that are worthy of attention. The majority of participants in the early group had not developed any formal understanding of spoken language prior to the implant fitting (i.e. having receptive spoken language skills equivalent to a 9 month old infant). The majority of children fitted later had developed some understanding of spoken language (i.e. equivalent to at least a child of 18 months of age) prior to the fitting of the cochlear implant. An age equivalent of 18 months means that the child is able to understand some spoken phrases used in highly contextually bound situations and a range of single words in decontextualised situations, but the quantity of words is restricted to below 50 items. Although the numbers of children are small it seems that there is more individual variation in the late group compared to the early group. Two children, *'cb'* and *'cl'* were at a pre-verbal level of understanding prior to cochlear implant fitting showing that they had not been able to develop any understanding of spoken language using hearing aids. Five children had developed some understanding of spoken language using hearing aids (to the level of an 18 month old child). Three participants in the late group *'sg' 'hm' and 'lp'*, had spoken receptive language scores, pre-implant, that were well above the rest of the participants in the late or early group. Their age equivalent language levels indicate that they had developed a receptive vocabulary well beyond 50 words. Despite having similar degrees of hearing impairment (measured by the PTA) it seems that *'sg', 'hm' and 'lp'*, **were** gaining some benefit from conventional hearing aids. This may explain why these three children were referred later for cochlear implant, but if we set these 3 children to one side we can see that most of the children (whether fitted early or late) had significant difficulties developing spoken language using conventional hearing aids.

Summary

If we are to be sure that the timing of the implant fit influences PA post implant fitting then it is desirable to show that apart from the timing of the fit children in the early and late groups were equivalent on factors either pre or post implant fitting that might impact on outcome. Given the role of age of diagnosis on later outcome for deaf children (i.e. Yoshinaga-Itano et al, 1998) and the potential role that age of diagnosis could have had on the timing of referral for cochlear implant fitting, perhaps the most significant finding for the purposes of this study is that there was no difference in the age of diagnosis between the two groups. We have not been able to identify any systematic differences between the groups prior to implant fitting (i.e. such as degree of hearing impairment, cause of deafness) therefore, the opinion of the clinical director (i.e. that referral date was influenced by local factors rather than child/family factors) emerges as the most likely explanation for the difference in the timing of the referral which meant that some children were fitted early and some later. It is feasible that other factors for which we have no objective data (i.e. perhaps related to degree of parental desire for the child to develop spoken language) may have influenced the timing of the referral. We now go on to consider the differences between the two groups at the start of the study.

Early and Late CI Groups at the start of the Study (October 1998)
The participant summary (table 4.3) shows; chronological age, mean age of cochlear implant fitting, duration of fit with the implant at time 1 (T1) and the t-score from the Matrices test of non-verbal reasoning which was administered at T1.

table 4.3 Participant Summary – CI Groups at T1

Group	Mean Age at Implant	CA at T1	Duration of Fit	BAS Matrices T-Score
CIE n=9	2.86 (.38)	7.52 (.98)	4.67 (.84)	52.78 (15.50)
CIL n=10	6.0 (.54)	9.10 (.97)	3.08 (.65)	58.20 (12.20)

standard deviations in brackets

By design, both groups had non-verbal reasoning skills within the normal range (mean t-score is 50, standard deviation is 15). Independent t tests were computed to assess the significance of the differences between the groups on these factors. The two groups differed significantly on age at time of implant fitting ($t = 14.602$; $p<.001$). The CIE group were significantly younger at the start of the study than the CIL group ($t = -3.51$; $p<.01$). The duration of fit also differed significantly between the group ($t = 4.613$; $p<.001$), the CIE group had been using their implants for longer than the CIL group. There was no significant difference on the Matrices test of non-verbal reasoning ($t = -.837$).

Educational Placement and Communication Mode

This study was not designed to assess the impact of communication mode on outcome following cochlear implantation. All the participants in the study had been exposed to signing at home or in school, both prior to or following the implant fit. At the time of the first data collection point six children in the early group were being educated in oral environments, 3 were in total communication (TC) environments. Five of the children in the late group were in oral environments and 5 were in TC environments. So, the groups were relatively well balanced in terms of communication method used within the educational environment at the time of the study. Likewise the educational settings were similar between the two groups. One child in the early group was in a special school for deaf children, 3 children in the early group were being supported in mainstream school and the remaining 5 children were in units attached to mainstream schools. In the late group, 1 child was in a special school for deaf children, 2 children were supported in mainstream schools and the remaining 7 children were in units attached to mainstream schools. The educational settings of the participants at the time of the study was relatively equivalent across the two groups. (This data is provided for each individual in table 4.2).

Implant Factors

The advantage of drawing the majority of the sample from one centre is that the audiological management of the children in the study will be the same. Discussions took place with the audiological scientists at GOSH regarding the implant factors that may differ between the two groups. In their opinion there were no staff changes, technology or assessment changes that would have produced a systematic difference between the two groups of children. In fact, if we accept that the expertise of staff increases over time then the late group (having received their implants after the early group) will have benefited from more specialist audiological assessment and management compared to the early group. All the children were fitted with the same implant (Nucleus 22) with the potential for 20 of these electrodes to be actively stimulated. The number of active electrodes changes over time. At the time of the first data collection (T1) the number of electrodes actively stimulated varied between the participants (see table 4.2 above). However, the lead audiological scientist stated that the number of active electrodes was a reflection of the **optimal** stimulation mode for the child (e.g. rather than arising from failed electrodes and therefore impoverished stimulation). Her view was that all the children in the study were receiving optimal stimulation based on the audiological management which took place during frequent mapping sessions at the centre. None of the children in the study had a high rate of non-attendance at the centre.

Summary

At the start of the study the two groups differed significantly on chronological age and duration of fit with the cochlear implant. However, in other ways the groups appeared to be well balanced (i.e. communication method, educational placement). Rather than attempting to make assumptions about the benefit of CI from educational placement and communication method the aim of presenting this information is to describe the participants as they were at the time of the start of the study. What we can glean from this description is that in this small sample the distribution of educational placement and communication method was similar between the two groups.

4.2.ii Standardised Measures and Procedures

Carers were given the option of their child being visited at school or at home. The majority of participants were visited in their schools (n=15), the rest were visited at home (n=4). Testing took place over two consecutive days. We were permitted four separate sessions which lasted up to 40 minutes each. Clinical concern about over-testing of the children prevented more intensive testing. The standardised tests were all administered in the first session. The experimental tests of syllable, rhyme and phoneme awareness were administered in three separate sessions. Details of the experimental tests and procedure for administration are given in Chapter 5.

Speech Perception – Clinical Data

It was not possible to ask participants in the study to attend the CI centre to undertake speech perception testing. Therefore, we used the speech perception results that were collected by the audiological scientists at GOSH as part of the child's clinical reviews. In the majority of cases, speech perception testing had taken place at GOSH within two months of experimental testing at T1. The speech perception results represent the performance of the participants at around the time when they were first seen by the experimenter (T1). At T1, open set speech perception test results (Manchester Junior Word List) were available for all the participants at GOSH. Analogous speech perception results were not available for the participants from the SOECIC programme (n=2).

The Manchester Junior Word List is an open-set speech perception test, administered at a voice level of 65db(A). A list of ten monosyllabic words is spoken, the participant either; repeats the word, signs the word or writes down the word that is perceived. A second list of ten monosyllabic words is tested without lip cues, the test is scored in the same way. This gives two measures of speech perception, audio-visual speech perception (AVSP), where the speech is seen and heard by the child, and audio speech perception (ASP), where speech is heard.

The British Picture Vocabulary Scales (Dunn, Dunn, & Whetton, 1982)

The British Picture Vocabulary Scales (BPVS), was administered by the experimenter. It was administered at time one (T1) and twelve months later, at time two (T2). The published procedure for administration of the BPVS was adhered to with some exceptions;

- the instructions given prior to task administration were spoken and signed to children who used manual communication,

- all children were advised that the words would not be signed, so they should look at the experimenter to help them know the word to choose.

Items were not signed to the deaf children. The results therefore, reflect the level of **spoken** receptive vocabulary. The BPVS is not routinely administered by speech and language therapists at the CI centres. Teachers were asked if the child had been tested on the BPVS within the previous six months. There was no case where it had been.

The British Ability Scales Test of Word Reading (Elliott, 1996)

The Word Reading test was administered by the experimenter at T1 and T2. The published procedure for administration was adhered to with some exceptions;

- the instructions given prior to task administration were spoken and signed to children who used manual communication,

- credit was given if the word was accurately read, mispronunciations were not scored as errors.

It was difficult to understand some utterances. In these cases, the child was asked to sign the word, or explain the word's meaning. Based on this information, the word read would be scored as correct or incorrect. For example, one item on the test is "babies". It was often difficult to hear whether the plural marker 's' had been marked in the child's speech. Clarification was sought, if the child's sign included the plural then the item was scored as correct, if only one baby was signed, then the item was scored as incorrect. This method of scoring is clearly subject to error. Therefore, when testing took place in the child's school, the result from the word reading test was discussed with the teacher. There was no case of a significant discrepancy between the age equivalent score from the word decoding test and the teacher's test results.

The British Ability Scales Matrices (Elliott, 1996)

The published procedure for administration was adhered to. The instructions were spoken and signed where appropriate. This assessment was administered at T1 only.

The British Ability Scales Recall of Digits Forward (Elliott, 1996)

The published procedure for administration was adhered to. The instructions were spoken and signed where appropriate. The test items were not signed. This test was administered at T1 and at T2.

Summary

In Part I of this chapter the methodological framework of the thesis has been given. The participants with cochlear implants have been described and potential differences between the two groups of CI participants both prior to and following the implant fitting have been explored. The hypothesis of this thesis is that acquisition of spoken receptive vocabulary will be the main determiner of the development of phonological awareness. It is argued that enhanced auditory perceptual ability afforded through the implant will impact on the development of receptive vocabulary. Therefore, before we embark on the main investigation of this thesis which is the development of phonological awareness, it is desirable to investigate the nature of the relationships between the timing of implant fitting, auditory perception and language development. In Part II we go on to investigate these relationships pertaining to the CI participants in the study.

PART II

Research Questions

1. **Does the early fitting of a cochlear implant improve speech perception?**

   It is predicted that the participants fitted with implants early will show advanced speech perception skills compared to the participants fitted later.

2. **Does the early fitting of an implant lead to enhanced spoken language skills?**

   It is predicted that the early fitting of an implant will benefit speech perception skills leading to better spoken language development post implant fitting.

3. **Does speech perception at Time 1 (T1) predict spoken language development at Time 2 (T2)?**

   It is predicted that speech perception at T1 will be related to development of spoken receptive language at T2.

4.3 RESULTS

4.3.i Does the early fitting of an implant enhance speech perception?

It is predicted that, due to the greater plasticity of the auditory pathways and cortex, participants fitted with cochlear implants before the age of five will have better speech perception than those fitted later. All the participants were fitted with the same cochlear implant, using the same processing strategy. Non-verbal reasoning skills were equivalent in the early and late groups. However, the duration of fit with the implant differed significantly, the CIE group had been using their implants longer than the CIL group.

The mean percentages correct for the audio-visual (AVSP) and audio (ASP) speech perception test, at T1, are given below for the CIE and CIL groups. Standard deviations are in brackets.

	AVSP	ASP
CIE		
n=7	91.67	86.17
	(6.95)	(8.72)
CIL	82.89	64.33
n=10	(15.32)	(22.1)

Test for Group Difference

The means show that the CIE group had better speech perception abilities both with and without lip-reading, compared to the CIL group. In order to test the significance of the observed difference, Mann Whitney tests were computed. The results showed that there was no significant difference between the groups on the audio visual speech perception test ($U = 19.5$, $z=-1.543$). The difference on the audio alone condition did reach significance at the 1 tailed level ($U = 17.5$, $z=-1.722$, $p=<.05$).

Controlling for Duration of Fit

In order to assess the impact of the age of fitting with an implant on speech perception at T1, a univariate analysis of variance with duration of fit as a covariate was performed. The dependent variable was the percentage correct on the ASP measure, group was the single fixed factor. The result showed that there was a significant effect of group ($F = (1,15)\ 8.823$; $p=<.01$) once duration of fit had been partialled out.

Summary

The CIE group was significantly better at perceiving single words in the absence of lip cues than the CIL group. The difference between the groups remained significant once duration of fit with the implant had been controlled. This suggests that early fitting with an implant improves speech perception. However, in order to draw firm conclusions regarding the impact of the timing of implantation, it would be necessary to show that the two groups did not differ on speech perception ability <u>prior</u> to implant fitting. Longitudinal speech perception testing is routinely carried out at GOSH. However, the tests used differed considerably between time points and between children, which meant that the data could not be synthesised for analysis. Longitudinal data on receptive language development was available from GOSH. This data is presented in the next section.

4.3.ii Does the early fitting of a cochlear implant enhance spoken language development?

The hypothesis is, that early implantation leads to enhanced speech perception, which contributes to the development of spoken language. A difference in speech perception at T1 was found, the early group had significantly better speech perception skills (without the aid of lip cues) than the late group. Therefore, a difference in spoken language is predicted between the groups. It is predicted that the CIE group will have advanced language skills. Results from the British Picture Vocabulary

Scales (BPVS) administered at T1 and T2 should show an advantage of early implant fitting. However, the differences in duration of implant fit between the groups at the time of testing needs to be considered because at the time this data was collected, duration of device use was not equal in the two groups.

4.3.iii British Picture Vocabulary Scales

The age equivalent (AE) and standard scores (std) from the BPVS at T1 and T2 are given below for the CIE and CIL groups.

	T1 – BPVS		T2 – BPVS	
	AE	Std	AE	Std
CIE	4.70	69.44	5.57	68.56
n=9	(1.68)	(15.69)	(2.36)	(17.83)
CIL	3.64	48.80	4.97	54.78
n=10 T1, n=9 T2	(1.32)	(10.81)	(1.78)	(15.77)

standard deviations in brackets

The age equivalent score from the BPVS at T1 was higher in the CIE group (4.70) than the CIL group (3.64). However, between T1 and T2 the actual change in receptive vocabulary age for the CIE group was .087 months (i.e. the difference between 5.57 at T2 and 4.70 at T1) and for the CIL group it was 1 year, 4 months (i.e. the difference between 4.97 at T2 and 3.64 at T1). This shows that participants fitted late, acquired more vocabulary over the 12 month period than participants fitted early. At T2 the CIE group still had a higher mean age equivalent score than the CIL group. The faster rate of vocabulary acquisition of the CIL group between T1 and T2 is evident in the narrowing of the difference in the degree of delay (represented in the standard score) between the two groups at T2

Test for Differences in BPVS AE and Std Score at T1 and T2

Independent t- tests were computed to test the significance of differences in BPVS AE and Std score at T1. The results showed that the difference in age equivalent score was approaching significance at the 1-tailed level ($t = 1.536$; p .07). The CIE group had higher receptive vocabulary ages than the CIL group. The difference in standard score was highly significant ($t = 3.370$; $p<.01$). The CIE group had significantly higher standard scores than the CIL group. At T2, the difference in age equivalent score was not significant ($t = .612$). The difference in standard scores was approaching significance at the 1-tailed level ($t = 1.74$; p .051).

Controlling for Duration of Fit

The difference in duration of cochlear implant use makes it difficult to interpret the signficance of these findings. At T2 the CIL group had been using their implants for same amount of time as the CIE group at T1. The CIL group's AE score at T2 was equivalent to the CIE group's AE score at T1, this would suggest that the duration of use rather than the timing of the implant fit was the critical factor in determining vocabualry acquisition. However, the respective standard scores at T1 and T2 are different for the groups. In order to assess the impact of age of fitting on vocabulary, a series of univariate analyses of variance were computed, with duration of fit as a covariate. The dependent variables were the age equivalent scores at T1 and T2 and the standard scores at T1 and T2. Group was the single fixed factor. The results showed that duration of fit was a significant covariate with BPVS age at T1 (F, 3.415; $p<.05$ – 1 tailed) and at T2 (F, 3.817; $p<.05$ – 1 tailed). Once duration of fit was held constant, group did not emerge as a significant factor in BPVS age at T1 (F, .080) or T2 (F, .953). Duration of fit was not a significant covariate of BPVS standard score at T1 (F, .235) or at T2 (F, .787). Once duration of fit had been controlled, group was a significant factor in BPVS std score at T1 (F, 3.366; $p<.05$ – 1 tailed), but not at T2 (F, .279).

Summary

At T1, the participants in the CIE group had higher receptive vocabulary ages than participants in the CIL group. However, this difference seems to be due to the difference in duration of fit with the implant, since duration of fit was a significant covariate with the age equivalent score at T1 and T2. There was a highly significant difference between standard scores at T1, the CIE group had higher standard scores than the CIL group. At T2, this difference was less significant because over time the CIL group's rate of development in spoken receptive vocabulary was faster than the CIE group. The difference in standard scores did not appear to be strongly related to duration of fit, since duration of fit was not a significant covariate with the BPVS standard score at T1 or T2. With the same length of device use, actual vocabulary ages were similar between the groups. The **degree of delay** in language development was greater in participants fitted after the age of five years. The likely explanation for this is the older age of the CIL group at the time of the implant fitting. This finding does not mean that the actual rate of vocabulary development is faster in the CIE group (i.e. facilitated by greater neural plasticity) in fact the evidence presented here is to the contrary, children fitted later acquired more vocabulary between T1 and T2.

4.3.iv Does speech perception at Time 1 (T1) predict spoken language development at Time 2 (T2)?

The CIE group had advanced speech perception at T1 compared to the CIL group and this did not seem to be caused by the difference in the duration of implant use. If speech perception is causally related to the development of spoken language, then speech perception at T1 will be strongly associated with measures of language delay at T2.

Time Lag Correlations

In order to test the hypothesis that speech perception is related to language delay, a time-lagged correlation between speech perception at T1 and the standard score from the BPVS administered at T2 was computed. If the hypothesis is correct then speech perception will be significantly correlated with language delay even when chronological age, non-verbal reasoning and duration of device use are controlled.

The data from the whole CI group was entered. Non-verbal reasoning is not predicted to be related to receptive language. Chronological age is not predicted to be strongly associated with the BPVS standard scores, since standard scores partially control for the effects of age. A relationship between the length of device use and vocabulary is predicted, but the relationship between speech perception and duration of device use should not be significant based on the findings presented earlier (4.1.3). The correlational matrix is in table 4.4.

table 4.4 Time-Lag Correlations

	BPVS T2 Std Score	CA	Matrices t Score T1	Duration of Fit At T1	AVSP At T1
BPVS T2 Std Score					
CA	-.204				
Matrices t Score T1	.223	.154			
Duration of Fit At T1	.653**	.007	.029		
AVSP At T1	.630*	-.639*	-.146	.234	
ASP At T1	.758**	-.719**	.005	.327	.942***

* $p < .05$, ** $p < .01$, *** $p < .001$

The results show that speech perception at T1, both audio visual and audio conditions, was significantly related to BPVS standard score at T2. Neither matrices non-verbal reasoning nor chronological age was significantly associated with the BPVS standard score, but duration of fit was. In order to test the specificity of the relationship between speech perception and receptive vocabulary, a partial correlation between speech perception (AVSP and ASP) and BPVS was computed, controlling for duration of fit. The results showed that when duration of fit was held constant, the relationship between audio visual speech perception at T1 and BPVS at T2 was no longer significant (r. 451), but the relationship between audio speech perception and BPVS remained significant (r. 642; $p < .05$).

Summary

The longitudinal association between audio speech perception at T1 and receptive vocabulary standard score at T2 shows that speech perception was a predictor of the rate of spoken vocabulary development.

4.4 DISCUSSION

The first aim of this chapter was to describe the overall design of the study, introduce the CI participants and describe the non-experimental measures that were used.

Participants

The constraints under which the study was conducted means that the sample of CI participants was smaller than that which was desirable. The small sample size coupled with the expected high variability between deaf children in the **same** group is a factor that will influence the power of the planned statistical analyses. Notwithstanding this, we have already seen from the literature reviewed in Chapters 2 and 3 that small group sizes are characteristic of prospective experimental research in the field of deafness (i.e. Dodd, 1976 n=10) and in the CI field (Tait & Lutman, 1994 n=9). Whilst small sample sizes of these studies places certain constraints on the findings, other aspects of the experimental design is strong and both of these studies have yielded important contributions to the literature. Similarly, whilst the small sample size of this study is a weakness other aspects of the design are strong relative to current research in the CI field (i.e. prospective, hypothesis driven, longitudinal study).

Measures

The constraints in terms of testing time with participants also shaped the selection of the measures. Given the main aim of the thesis, (i.e. to assess the phonological awareness skills of deaf children with cochlear implants) the majority of testing time was prioritised for the experimental tests of PA. This meant that there was less time to administer the relevant background measures which were important in order to address other questions (i.e. the relationship between PA and word reading). The choice of the reading assessment was partly made on the basis of speed of administration, but the choice of a word recognition test was also made on theoretical grounds. If deaf children are able to use phonological awareness to aid reading development then evidence of decoding skills underpinned by PA skills should impact most on word recognition. Ideally, we would have also included a reading comprehension task such as the Neale Analysis of Reading Ability. However, the constraints regarding testing time with participants meant that it was not possible to directly assess reading comprehension. Word recognition or decoding may be an accurate proxy measure of reading comprehension in hearing children as suggested by Stanovich (1991) however, the same relationship between decoding ability and comprehension does not necessarily occur for deaf children (Paul, 1998). In this study gaining a reading age for the CI group was important because of the planned comparison with hearing children who are at the same reading level. In order to ensure that the test of word recognition did yield a reasonably accurate measure of the child's general reading level, reading attainment based on teachers' assessments was sought. There was a very high degree of agreement between the age equivalent score derived from the BAS test of word reading and the teacher's own assessment results. In fact, in all cases the results (i.e. experimental and teacher assessments) were within 3 to 6 months of each other. There were differences in the timing of these assessments (i.e. experimental and teacher assessments) and not all children were tested in school so contact was not made with all the teachers. The term 'reading age' as used in this thesis refers to the number of words accurately recognised by the child which itself may or may not be an accurate guide to the child's reading comprehension age.

A supplementary research question of this thesis is to investigate the impact of the timing of cochlear implant fitting on the development of phonological awareness. In this chapter it has been shown that the two CI groups were similar along important dimensions (i.e. age of diagnosis and degree of hearing impairment) pre implant fitting. Three children fitted later with an implant were identified who had developed a degree of spoken language prior to cochlear implant fitting that was advanced compared to the rest of the CI participants. This strongly suggests that these three participants were different from the rest of the CI participants in that they were able to make use of residual hearing with hearing aids to develop spoken language. It seems likely (given the age equivalent receptive language levels) that these three children experienced the 'vocabulary burst' (common prior to the end of the second year of life in hearing children) **before** they had their cochlear implant. Given the insufficient level of detail available regarding language development pre-CI it is not possible to show this unequivocally, but according to the theoretical framework of Locke (1997) these children could have stored enough utterances and words prior to the CI to 'switch on' the analytical and computational mechanism. Assuming that the acquisition of the required volume of words occurred within the sensitive period (i.e. before the end of the third year of life) we would predict that these children would possess better phonological awareness compared to the other participants in the late group since their phonological representations are likely to have undergone some systematic segmental restructuring prior to implant fitting. This possibility is explored in later chapters.

In this chapter the impact of early CI fitting on speech perception and subsequent receptive vocabulary was explored. The highly significant association between audio speech perception at T1 and spoken receptive vocabulary at T2 shows that speech perception is related to the development of spoken language in children with cochlear implants. The supplementary hypothesis was that speech perception would be advanced in participants fitted earlier, due to greater plasticity of the auditory pathways before the age of 5 years. This in turn would lead to enhanced development of spoken language. The younger participants, who were fitted with implants earlier were significantly better at recognising speech in the absence of lip cues than participants fitted later. At T1, participants fitted early had higher age equivalent scores on the BPVS although this was due to longer device use. Standard scores, on the BPVS differed significantly at T1 and at T2 between the groups and this was not likely to be due to the difference in duration of fit. A caveat is required here regarding the sensitivity of the BPVS as a measure of receptive language development in deaf children. There is no currently available standardised assessment for spoken receptive vocabulary for deaf children. In order to make reliable and robust conclusions about the rate of vocabulary development in deaf children a new test should be devised which assesses understanding of the words that the child has been exposed to given their level in the National Curriculum. Assessing language development post cochlear implant fitting was not the main aim of this thesis and it was not within the scope of this study to devise a new assessment. However, the development of a sensitive measure of receptive vocabulary (standardised on deaf children) should be a serious consideration for anyone undertaking future research on language and literacy development in deaf children.

Conclusion

A number of results that have emered from the data regarding the impact of the timing of the implant fit and the relationship between speech perception and receptive language will need to be borne in mind as we go on to consider the main research questions of the thesis. The results presented here concur with the current research view that early implantation is better for the development of speech perception and spoken language development. The conclusion based on this data is that early cochlear implantation reduces the degree of delay in spoken language development because it ameliorates the extent of the initial language gap. The fitting of a cochlear implant early prevents the chasm developing in spoken language skills between deaf and hearing children, but older children can make significant developments in spoken language following the fitting of a cochlear implant. Whilst it might be clearly desirable to prevent the initial language gap by fitting an implant early, should this mean that older children are denied an implant? Understanding the interaction between the timing of the implant, language development and the child's chronological age in relation to spoken language outcomes post implant fitting is complex. In the mean time questions that might be simple to frame.... *"How long can I wait to see if my child develops language without an implant?* ..... remain difficult to answer.

In the next chapter the development of the phonological awareness of the deaf children fitted with cochlear implants is presented.

Chapter 5 – Phonological Awareness in CI Participants

5.1 INTRODUCTION

In Chapter 4, it was found that early fitting with a cochlear implant benefits speech perception and attenuates the size of the gap in spoken receptive vocabulary between deaf and hearing children. In this chapter the phonological awareness skills of the cochlear implant users is investigated. In this thesis the prediction is that early vocabulary development is causally related to the development of a phonologically structured lexicon. Therefore, children fitted early are predicted to have advanced phonological awareness compared to those fitted later. In this chapter the impact of early implant fitting on phonological awareness is investigated.

Designing fair tests of phonological awareness for young deaf children poses enormous challenges. The difficulties associated with previous experiments is outlined in Chapter 2. The low language levels common in deaf children mean that vocabulary should be chosen carefully so that only words that are likely to be known by young deaf children should be used. In addition, the instructions for the task must be unambiguous and presented in a clear and accessible way so that even children with delayed language comprehension can participate. In this chapter the new battery of phonological awareness tests is described. The tests were specially designed for use with young deaf children. The vocabulary used in the tasks was highly familiar to ensure that the participants knew the items presented. The cognitive demands of the tasks was kept low, a matching to sample task was used at each linguistic level. It is assumed these PA tasks measure of the degree to which phonological representations are segmentally organised. It has been reported that in hearing children, performance on PA tasks is related to the linguistic unit under investigation. Syllable awareness develops before rhyme awareness, which develops prior to phoneme awareness. There have been no studies investigating the phonological awareness development of deaf children with cochlear implants. However, the literature reviewed in Chapter 2, shows that there is some evidence to support the view that phonological awareness in deaf children follows the same pattern as that of hearing children.

Research Questions

1. **Is there an effect of linguistic unit on phonological judgements in children with cochlear implants?**

   It is predicted that the size of the linguistic unit will influence phonological judgements; awareness of syllables will be easier than rhyme awareness, which will be easier than phoneme awareness. If phoneme awareness was found to be above chance level, it was predicted that singleton onset trials would be easier than clustered onset trials.

2. **What is the developmental pattern of phonological awareness in children with cochlear implants?**

   Improvement on phonological awareness measures over time was predicted, to show syllable awareness preceding rhyme awareness, which would precede phoneme awareness.

3. **Is there an effect of age of fitting with CI on phonological awareness?**

   It is predicted that children fitted with a cochlear implant early would have better phonological awareness than children fitted late.

5.2 METHOD

5.2.ii Participants

The participants are the same participants presented in Chapter 4.

5.2.iii Measures and Procedures

Three measures of phonological awareness were designed; a syllable task, a rhyme task and a phoneme task. The following factors were considered important in task design and administration;

- the cognitive demands of the tasks should be equal across the linguistic levels
- the tasks should enable the investigation of the extent to which deaf children rely on orthographic knowledge to make phonological judgements
- the items used should be highly familiar, early acquired words, presented as pictures
- the tasks should use computer presentation, so that response times could be measured (and to facilitate motivation and attention of the participants)
- pre test training and familiarisation with the pictured items in the tasks should be given, so that the vocabulary was familiar to the deaf children. The pre test training should be equal across the linguistic levels.

The components of the experimental tests were as follows:

1) Receptive vocabulary test – words used in the experiments

2) Naming test – words used in the experiments

3) Training
   a) generic awareness of phonological unit
   b) specific awareness of phonological unit

4) Practice Trials
   with picture cards
   with computer

5) Experimental Trials

Each experimental test, with all its components, was administered in one session, which lasted between 30 to 40 minutes. The order of presentation of these components was fixed as outlined above. Children were seen individually in a quiet room either in the school, or in a few cases, the child's home. The experimenter sat at a 90 degree angle to the child.

All participants completed all three experimental tasks at T1 and twelve months later at T2. The tests were administered in different sessions. The order of test administration was counter balanced across the participants. The administrative procedure for the receptive test and naming test are given below.

Receptive Vocabulary Test Procedure

This test consisted of all the pictures used in the experimental trials. Four black and white line drawings bounded with frames measuring 4cm by 4cm were presented on a card. The experimenter named each word on the card and the child was asked to point to the corresponding picture. The pictures were assigned into quadruplets using a random number generation system.

The experimenter introduced the task by saying;

Soon we are going to play on the computer, but first I've got some pictures for you to look at. See there are four pictures (experimenter points to all four pictures*). I'm going to say one of them and you have to find the picture. If you don't hear the word properly ask me and I'll say it again.* These instructions were spoken and signed, where appropriate.

If the child did not know the item, immediate feedback/training in that concept was given. For example if the child did not know the word "daffodil", the training would have been something like this; "*this is a flower, you know that, but it's got a special name, listen, it's a daffodil, daffodils are yellow and they come out in Spring time, it's a daffodil*". Semantic cues were used to teach the vocabulary. The phonological structure of the word was not focused on in training; the child's attention was not directed towards the first sound, the rime or the number of beats in the word. On completion of the test, items that were unfamiliar to the child were re-tested and, if necessary, the training for that item was repeated. The majority of the items were familiar to the children, training was given for approximately 10% of the items, with repetition necessary for approximately 5% of the items.

Naming Test Procedure

Each picture used in the experimental tests was presented as a single item on a card measuring 12 cm by 12 cm. The child was asked to name the items.

Now this time I want you to say the words for me. Here are the pictures, they are the same as the pictures you have just seen. I want you to have a look at the picture and tell me its name. If you can't remember the name, don't worry about it, I can give you a clue. These instructions were spoken and signed.

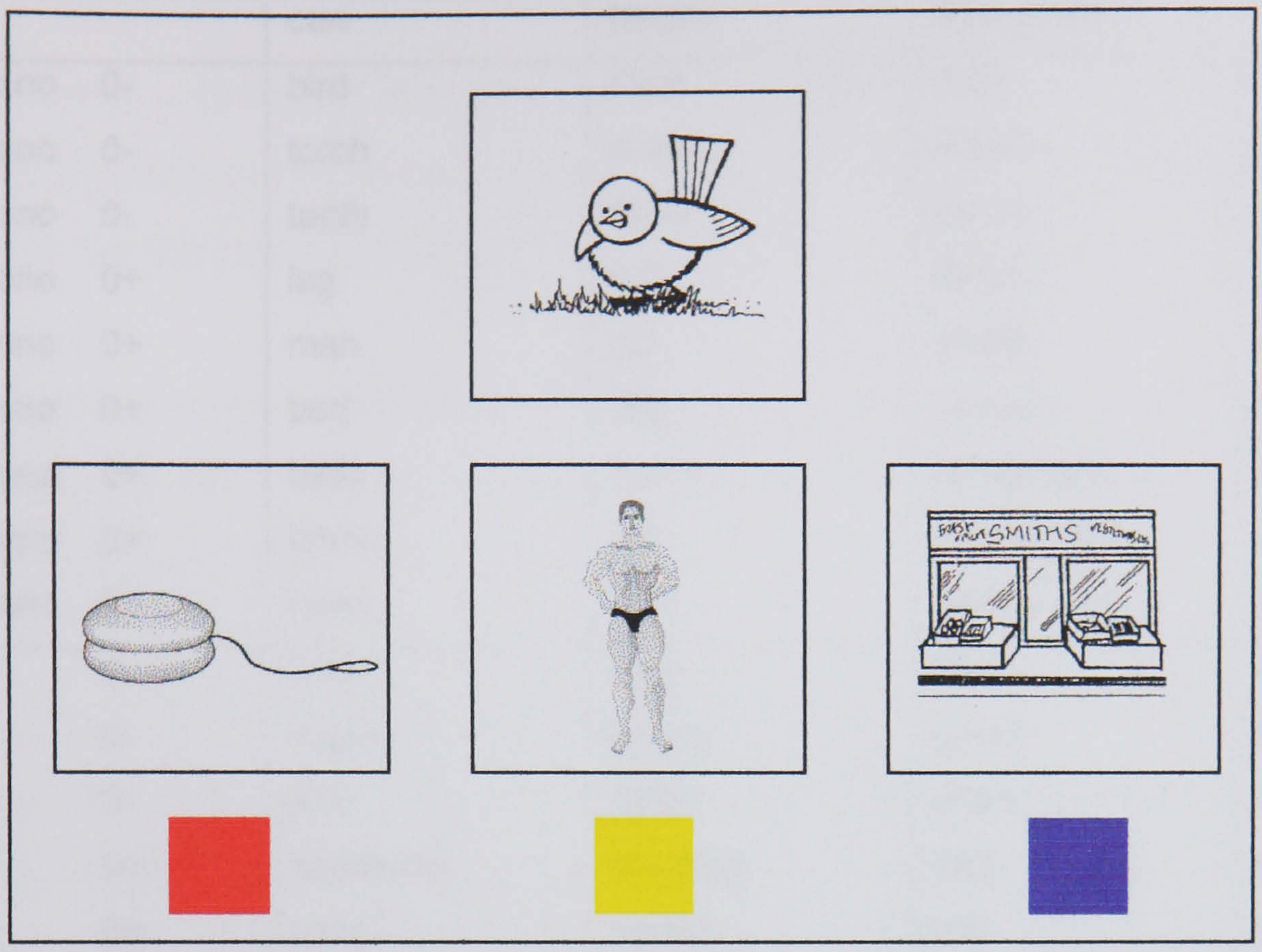
If a child failed to name an item, a semantic cue was given, for example *"It's a yellow flower"*. If this failed to elicit the name, then a forced choice question was given with a semantically related foil, for example, *"Is it a daffodil or a poppy?"* Items incorrectly named were treated in the same way; feedback was given followed by a semantic cue, and finally by the forced choice question, if necessary.

Each experimental task is described below, details of the training, which was specific for each experimental task is also given.

5.2.iv The Syllable Test

This test consisted of 27 trials in total. Each trial comprised four line drawings presented on a computer screen. One picture, presented at the top centre of the screen, was the cue. Three more pictures appeared underneath this cue, one of which (the target) shared the same number of syllables as the cue. The items were named by the experimenter as they appeared on the screen. The participant made his or her response by pressing a colour coded key on a button box. There was a short pause before the next trial was presented. The trials were presented in a random order and the position of the target picture was counterbalanced across the three serial positions. An example of what was presented on the computer is given in figure 5.1 (items; bird, yoyo, body, <u>shop</u>).

Figure 5.1 A Syllable Test Trial



The cues were either mono, di or tri syllabic. There were nine of each type. Within these sets, three of the trials were orthographically incongruent. In these trials, all the words depicted on the screen had the same number of letters. If the child was relying on an orthographic strategy (i.e. matching the cue and target based on knowledge of the visual length of the words) then performance on these trials could not be above chance. The distracters were either semantically related to the cue (designated ‘s’) or shared the same onset with the cue (designated ‘ph’). Within the sets, three trials had both distracters (s) and (ph), the rest of the trials had an unrelated distracter and either a semantic or phonological distracter. Care was taken to ensure that on the di and tri syllabic trials the target item was not always an object that was the longest or biggest item of the three choices.

table 5.1 Syllable Test Trials

	cue	target	distracter	distracter
mono 0-	bird	shop	yoyo	body (ph)
mono 0-	torch	nurse	camel	tiger (ph)
mono 0-	teeth	fence	lemon	happy (s)
mono 0+	leg	cot	tissue	sandal (s)
mono 0+	man	zip	castle	monkey (ph)
mono 0+	bed	dog	jumper	pillow (s)
mono 0+	bath	comb	button (ph)	shampoo (s)
mono 0+	book	fish	bucket (ph)	pencil (s)
mono 0+	nose	kite	needle (ph)	perfume (s)
di 0-	baby	lego	chin	doll (s)
di 0-	sugar	penny	ghost	shark (ph)
di 0-	jelly	table	witch	mouth (s)
di 0+	sandwich	trousers	bag	sun (ph)
di 0+	toilet	spider	bus	tin (ph)
di 0+	dolphin	tractor	pie	sea (s)
di 0+	donkey	rubber	dice (ph)	pig (s)
di 0+	finger	circle	fan (ph)	thumb (s)
di 0+	teacher	carrot	tail (ph)	boy (s)
tri 0-	banana	domino	strong	bridge (ph)
tri 0-	potato	museum	switch	cheese (s)
tri 0-	tomato	violin	church	tights (s)
tri 0+	kangaroo	triangle	red	cup (ph)
tri 0+	elephant	computer	door	grey (s)
tri 0+	umbrella	dinosaur	tick	rain (s)
tri 0+	strawberry	photograph	string (ph)	pear (s)
tri 0+	crocodile	aeroplane	crane (ph)	snake (s)
tri 0+	butterfly	pyjamas	bike (ph)	ant (s)

The child had to make a judgement about which of the three pictures had the same number of syllables as the cue picture. Two dependent variables were measured, accuracy and reaction times for correct responses.

5.2.v Procedure for Syllable Test

Training – General Phonological Word Length Awareness

The training period lasted approximately 15 minutes. All instructions were spoken and signed where appropriate. The experimenter said;

We are going to think about words and we are going to think about how words sound. I know that you are deaf and it's difficult for you to think about sounds, but I want us to try.

Now do you know that some words sound long and some words sound short (pause) some words sound long (pause) *some words sound short* (on repetition of this phrase the word long was produced with an elongated vowel and the word short was produced with a very short vowel).

Can you think of any long words? (all responses were recorded, feedback was given so that if a child produced a word that was physically long the experimenter said *"yes a train is a long thing, but remember we are thinking about if the word sounds long"*)

I know a long word, it's a funny word, are you ready super-cala-fradg-ilisitc-expi-ali-do-tious" (the syllabic structure of the word was emphasised by placing equal stress on all syllables together with a slight forward head movement for each syllable.

Can you think of any short words? (The child's response was recorded and feedback was given).

Training – Specific Syllable Number Awareness

The aim of this section was to introduce syllables in an explicit way. The counting of syllables was encouraged using the following script and materials. The word 'syllable' was never used, unless the child themselves first used the word.

I've got some pictures here. One of these words is long (pause) it sounds long. Listen to the words: bat, sponge, caterpillar, which one sounds long? (the response was recorded as either correct or incorrect)

In the case of an incorrect response - *"no listen again, this is the word that sounds long caterpillar"* (pause) *"bat and sponge are short words they sound short" "bat, sponge, caterpillar sounds long"*

In the case of a correct response – *"yes that's right caterpillar sounds really long.* The word was repeated and the shortness of 'bat' and 'sponge' was reinforced in exactly the same way as if the child's response had been incorrect.

Caterpillar is a long word, it sounds long, I don't mean that it is the biggest thing, I don't want us to think about the size of the thing, we are thinking about the way words sound. Have a look underneath. The child was encouraged to lift a flap on the picture of the caterpillar. Underneath the four syllables were colour coded and superimposed over the picture (see Appendix A). The colour coded syllables were pointed to as each syllable was spoken. *It's got lots of chunks – it's a long word. What about bat and sponge have a look (child lifts flaps). See they are short words they only have one chunk, bat, sponge.*

Counting Syllables

In this extension of specific training on syllables, children were encouraged to count the syllables in their own name and in the experimenter's name.

Let's see about your name, how many chunks has it got. Do you know?

The experimenter says child's name and puts up finger relating to the syllables, repeats child's name pointing to the fingers again. Child is asked to copy *experimenter "let's do it together, ready ...." it's got X chunks.* The child's name is repeated with the number of syllables represented on the experimenters fingers. The number of syllables in the experimenter's name was also counted.

Training Trials

Three training trials, using black and white line drawings were given. The items were named for the child starting with the cue word and then three possible choice items. The child was encouraged to think about how many 'chunks' the cue word consisted of. *You have to think about this top word, think how many chunks has it got*, the word was then repeated for the child. *Then you have to think about these words underneath* (words repeated for the child). *One of these words has the same number of chunks as the top one. Which one is it?* Feedback was given and the words were repeated *"that's right, they both have two chunks – they sound the same".* In the case of an incorrect response the child was told it was wrong and the experimenter went through the trial, showing the correct choice. Finally, all children were reminded that during the trials they needed to be focusing on the sound of the word rather than thinking about visual characteristics of the orthographic pattern or finger spelling. *"Remember we are thinking about the way the words sound. Don't think about the finger spelling or the way the word is written, think about the sound of the word and how many chunks the word has got".*

Computer Practice Trials

Four computer practice trials were administered. The aim was to familiarise the child with the computer and with making a speeded response using the button box. The training trials were:

cue	target	distracter	distracter
sock	worm	envelope	cucumber
doctor	rocket	wall	shoe
hand	boat	rainbow	coffee
daffodil	spaghetti	ship	bow

The following instructions were given;

Now you are going to do the same game on the computer. You have to think about the picture at the top – how many chunks has it got, then find the one underneath that has got the same number of chunks. If you think it's the picture over here, then you press the yellow button, if you think it's the one in the middle, you press the red button and if you think it's the one at the end then press the blue button. Wait for me to finish saying all the words then you press the button to choose the one that has the same number of chunks as this one at the top.

Inside the computer is a little clock, it's going to see how fast you can go. I want you to think about the sound of the words, it's better to think hard and then decide don't worry too much about the clock. Put your hand here so that you are ready to press the button. Are you ready? Off you go.

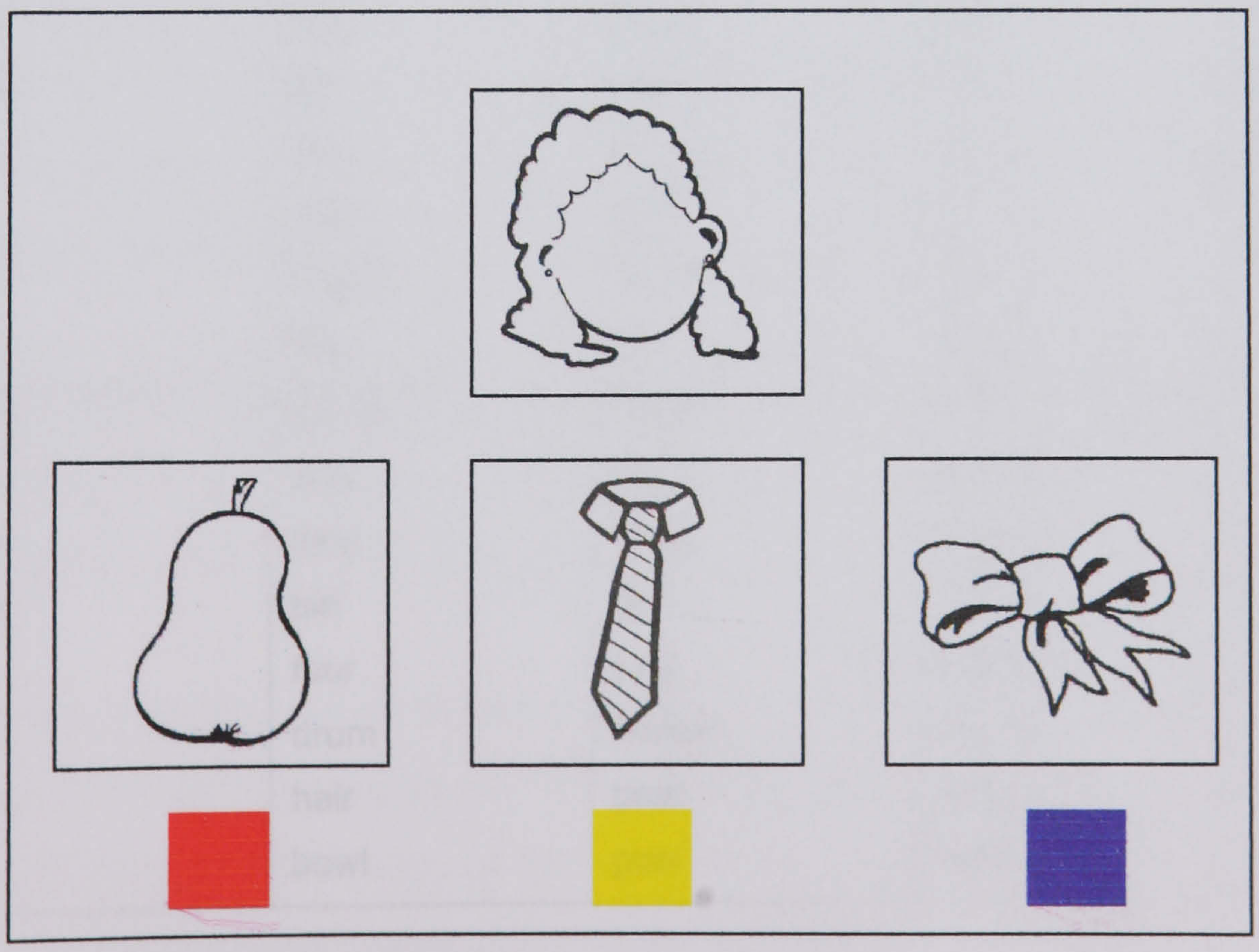
Feedback was given after the four computer trials. Then the experimental test was administered. All children were reminded of the need for speed and accuracy. They were also told that the experimenter would not play the game with them, that they had to decide for themselves.

During the experimental trials some children sought approval of their choice from the experimenter. Non-contingent feedback was given, for example, the experimenter would say *"you want the blue one"*. No indication of whether their choice was correct or incorrect was given. If a child asked for repetition of a word or words, one repetition was given, the trial where repetition was required was recorded.

5.2.vi The Rhyme Test

This test consisted of 24 trials in total. Each trial comprised four line drawings presented on a computer screen. One picture, presented at the top centre of the screen, was the cue. Three more pictures appeared underneath this cue, one of which (the target) rhymed with the cue. The items were named by the experimenter as they appeared on the screen. The participant made his or her response by pressing a colour coded key on a button box. There was a short pause before the next trial was presented. The trials were presented in a random order and the position of the target picture was counterbalanced across the three serial positions. An example of a trial from the rhyme test is in figure 5.2 (the items are; hair, <u>pear</u>, tie, bow).

Figure 5.2 A Rhyme Test Trial



Half of the cues and targets shared the same rime spelling, these are referred to as orthographically congruent trials (0+). For the other half of the trials, the spelling of the rime unit differed (incongruent trials, 0-). There were twelve trials of each type. Eight of the 24 trials had a semantic distracter, where an item was related in meaning to the cue. Eight of the 24 trials had a phonological distracter, where an item had the same initial onset as the cue. Eight of the 24 trials had both a semantic and phonological distracter.

table 5.2 Rhyme Test Trials

	cue	**target**	**distracter**	**distracter**
0+	sock	clock	doll	hat (s)
0+	tree	knee	pie	bird (s)
0+	hand	sand	salt	glove (s)
0+	leg	peg	nail	arm (s)
0-	one	run	bike	two (s)
0-	shoe	blue	gold	feet (s)
0-	light	kite	duck	sun (s)
0-	draw	floor	bath	pen (s)
0+	wall	ball	tie	wig (ph)
0+	tap	map	ring	ten (ph)
0+	bag	flag	kiss	bee (ph)
0+	fan	man	coat	fox (ph)
0-	fruit	boot	door	frog (ph)
0-	soap	rope	cot	six (ph)
0-	whale	snail	cup	win (ph)
0-	key	sea	farm	king (ph)
0+	nurse	purse	ill (s)	night (ph)
0+	pink	sink	red (s)	pull (ph)
0+	face	race	nose (s)	fork (ph)
0+	bin	pin	can (s)	bed (ph)
0-	four	saw	eight (s)	fat (ph)
0-	drum	thumb	toy (s)	drip (ph)
0-	hair	pear	bow (s)	hill (ph)
0-	bowl	goal	knife (s)	bus (ph)

The children had to make a judgement about which of the three pictures rhymed with the cue picture. The two dependent variables measured were accuracy and reaction times for correct responses.

5.2.vii Procedure - Rhyme Test

The receptive vocabulary and naming tests were administered in the same way as for the syllable test.

General Rhyme Awareness

General rhyme awareness was introduced in the following way.
We are going to think about words and we are going to think about how words sound. I know that you are deaf and it's difficult for you to think about sounds, but I want us to try.

Now my name is Deborah. This is my favourite animal (a picture of a zebra is placed in front of the child). *It's a zebra. Deborah* (pause) *zebra. Why do you think I like the zebra?* (all responses were recorded),

Reinforcement of responses that were linked to the sounds of the two words was given. For example, the child may say "they're the same" or, "they rhyme", then the experimenter said, "*yes, you're right, Deborah and zebra sound the same at the end*".

The word 'rhyme' was only used if a child used it first, otherwise the phrase, 'sound the same at the end' was used throughout this experiment to refer to the phonological unit of the 'rime'.

When a child gave a response that did not correspond to the sound of the words feedback was given. If a child reasoned that the experimenter liked the zebra because of some semantic attribute of the animal, for instance because it was stripy, then the following training was given; "*yes zebras are stripy, but remember we are thinking about the way words* *sound, listen again to the words Deborah* (pause) *zebra, why do you think I love the zebra?"* (responses were recorded).

If a child was still unable to make a judgement based on the sounds of the two words the experimenter said, *"listen again to the sounds of the words zebra* (pause) *Deborah, they sound the same at the end, zebra* (pause*) Deborah".*

Rhyme Generation

The child's own name was used as a basis for more rhyme awareness. *"Let's think about your name X. Can you think of a word that sounds the same at the end, X*?"(pause).

The child was encouraged to generate non-words, so that if no responses were forthcoming the experimenter said *"well we could make up some silly words that sound the same as your name "* (one example was given) (pause for response).

If a response was given based on an alliterative strategy then the experimenter emphasised the end sound in the words. This was achieved by refocusing on the pair 'zebra/Deborah' where emphasis was placed on the rhyme using stress. The difference between the onsets of the words was illustrated using finger spelling.

Where the child gave a correct rhyming response, positive feedback and reinforcement were given, "*angel/bangel, that's right, they sound the same at the end, angel/bangel*".

Training Trials

Three training trials using black and white line drawings were given. Then the computer training trials were given; they were:

cue	target	distracter	distracter
mop	hop	book	chin
phone	bone	shop	fish
zip	lip	hook	worm
stick	lick	comb	dice

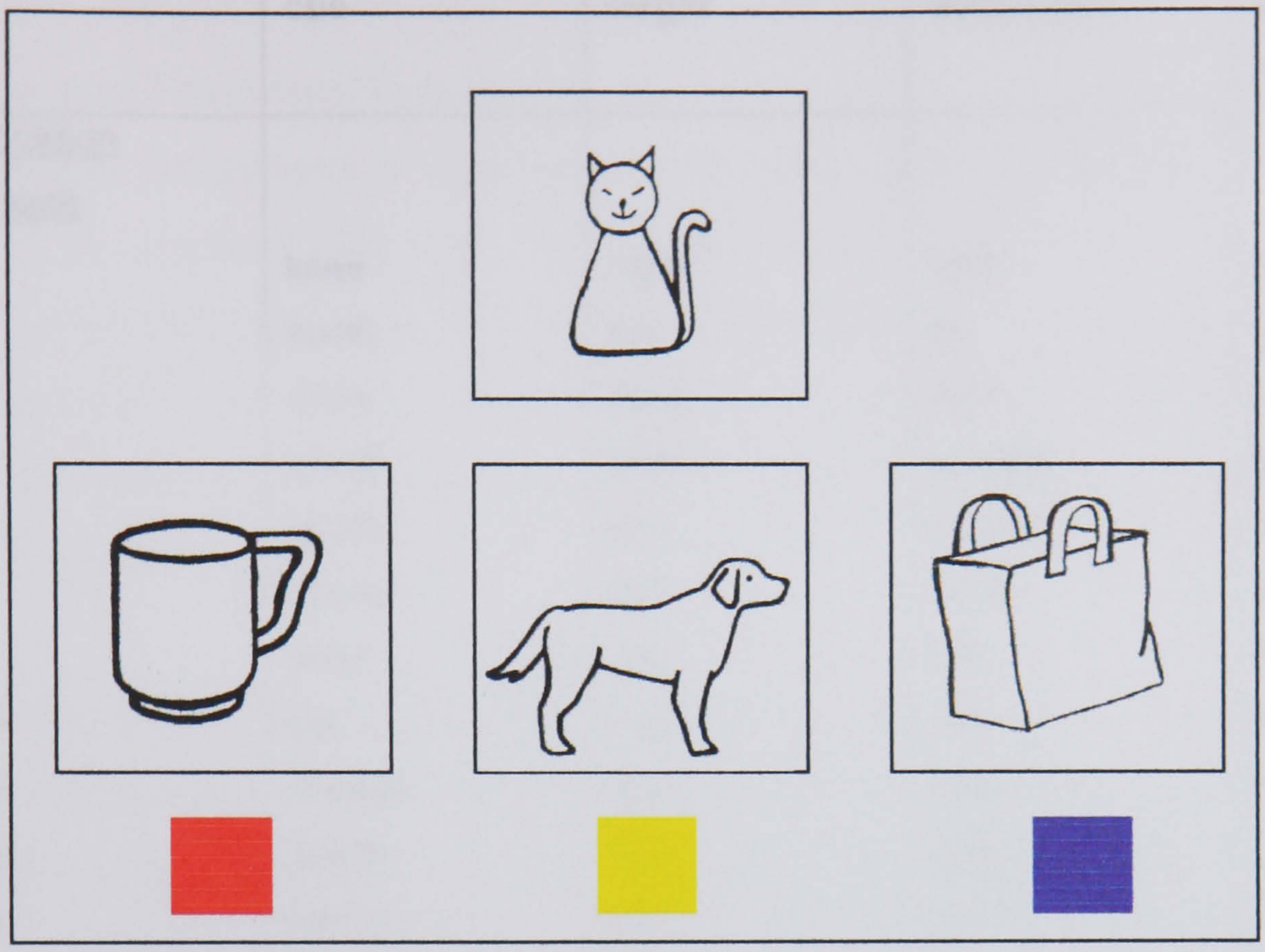
The procedure for administration of the training trials was the same as described for the syllable test.

5.2.viii The Phoneme Test

This test consisted of 28 trials in total. Each trial comprised four line drawings presented on a computer screen. One picture, presented at the top centre of the screen, was the cue. Three more pictures appeared underneath this cue, one of which (the target) shared the same onset as the cue. The items were named by the experimenter as they appeared on the screen. The participant made his or her response by pressing a colour coded key on a button box. The trials were presented in a random order and the position of the target picture was counterbalanced across the three serial positions. An example is given in figure 5.3 (items are; cat, <u>cup</u>, dog bag).

The cues had either singleton onsets or clustered onsets. There were fourteen of each type. Within these sets, half of the trials were orthographically incongruent, where the initial phoneme of the target was not represented by the same grapheme as the cue (0-). The other half of the trials were orthographically congruent, the spelling of the cue and target was the same (0+). All the trials had an item that was semantically related to the cue. The other distracter was chosen to be close to the cue in terms of phonetic features.

Figure 5.3 A Phoneme Test Trial



The children had to make a judgement about which of the three pictures had the same initial sound as the cue picture. The two dependent variables measured were accuracy and reaction times for correct responses.

table 5.3 Phoneme Test Trials

	cue	**target**	**distracter**	**semantic distracter**
Singleton Onsets				
0-	knee	night	milk	sock
0-	comb	key	tie	hair
0-	circle	sand	tank	shapes
0-	cough	kettle	garage	tissue
0-	giraffe	jelly	doctor	lion
0-	phone	fish	hook	ear
0-	wrist	red	sea	arm
0+	cat	cup	bag	dog
0+	cheese	chin	feet	bread
0+	ladder	light	ring	wall
0+	pencil	palm	mouth	book
0+	finger	fox	vase	hand
0+	ball	bone	man	goal
0+	farm	fat	van	cow
Clustered Onsets				
0-	queen	cot	bush	gold
0-	crab	kitchen	teacher	whale
0-	climb	kiss	bird	leg
0-	swim	ceiling	tiger	boat
0-	clock	kite	gate	three
0-	skirt	circus	doll	coat
0-	cloud	king	bath	rain
0+	tree	tent	map	grass
0+	star	six	nose	moon
0+	plate	pig	catch	fork
0+	scarf	sun	bike	glove
0+	snake	soap	teeth	worm
0+	blue	bin	peg	white
0+	glue	ghost	cage	pen

5.2.ix Procedure - Phoneme Test

General Phoneme Training

General awareness of phonemes was given using the following script. *Now my name is Deborah. (the initial phoneme 'd' was fingerspelled) "d for Deborah, shall I tell you things that I like, listen I like dogs, ducks, doughnuts, dishes, and dots. Why do you think I like dogs, ducks, doughnuts, dishes and dots?* (the initial phoneme of the words was stressed)

Reinforcement of responses that were linked to the initial sound of the words was given. For example, the child may say "they're the same" or, "they've all got 'd', then the experimenter said, "*yes, you're right, they all sound the same at the beginning, the very first bit is the same*".

The phrases, 'sound at the beginning' and 'the very first bit' were used throughout this experiment to refer to the phoneme.

When a child gave a response that did not correspond to the sound of the words feedback was given. If a child reasoned that the experimenter liked the things because of some semantic attributes of the items, for instance because doughnuts had sugar, then the following training was given; "*but remember we are thinking about the way words sound, listen again to the words Deborah* (pause – list repeated) , *why do you think I like all these things?*

If a child was still unable to make a judgement based on the sounds of the two words the experimenter said, *"listen again to the sounds in the words* (the list was repeated) *they all sound the same at the beginning, the very first bit is the same* (list repeated).

Alliteration Generation

The child's own name was used as a basis for more phoneme awareness. *"Let's think about your name X. Can you think of a word that sounds the same at the beginning?"*(pause).

The child was encouraged to generate non-words, so that if no responses were forthcoming the experimenter said *"well we could make up some silly words that sound the same as your name at the beginning"* (one example was given) (pause for response).

If a response was given based on a rhyme strategy then the experimenter emphasised the beginning sound in the words. This was achieved by refocusing on the list above ('d' words) where emphasis was placed on the initial phoneme through the use of stress.

Where the child gave a correct alliterative response, positive feedback and reinforcement were given, *"Jack/jumper, that's right, they sound the same at the beginning, Jack/jumper"*.

Finally, all children were reminded that during the trials they needed to focus on the sound of the word rather than visual characteristics of the orthography or finger spelling strategy. *"Remember we are thinking about the way the words sound. Don't think about the finger spelling or the way the word is written, think about the sound of the word and how it sounds at the beginning"*.

Training Trials

Training trials were administered in the same way as described for the syllable test. The computer training trials were;

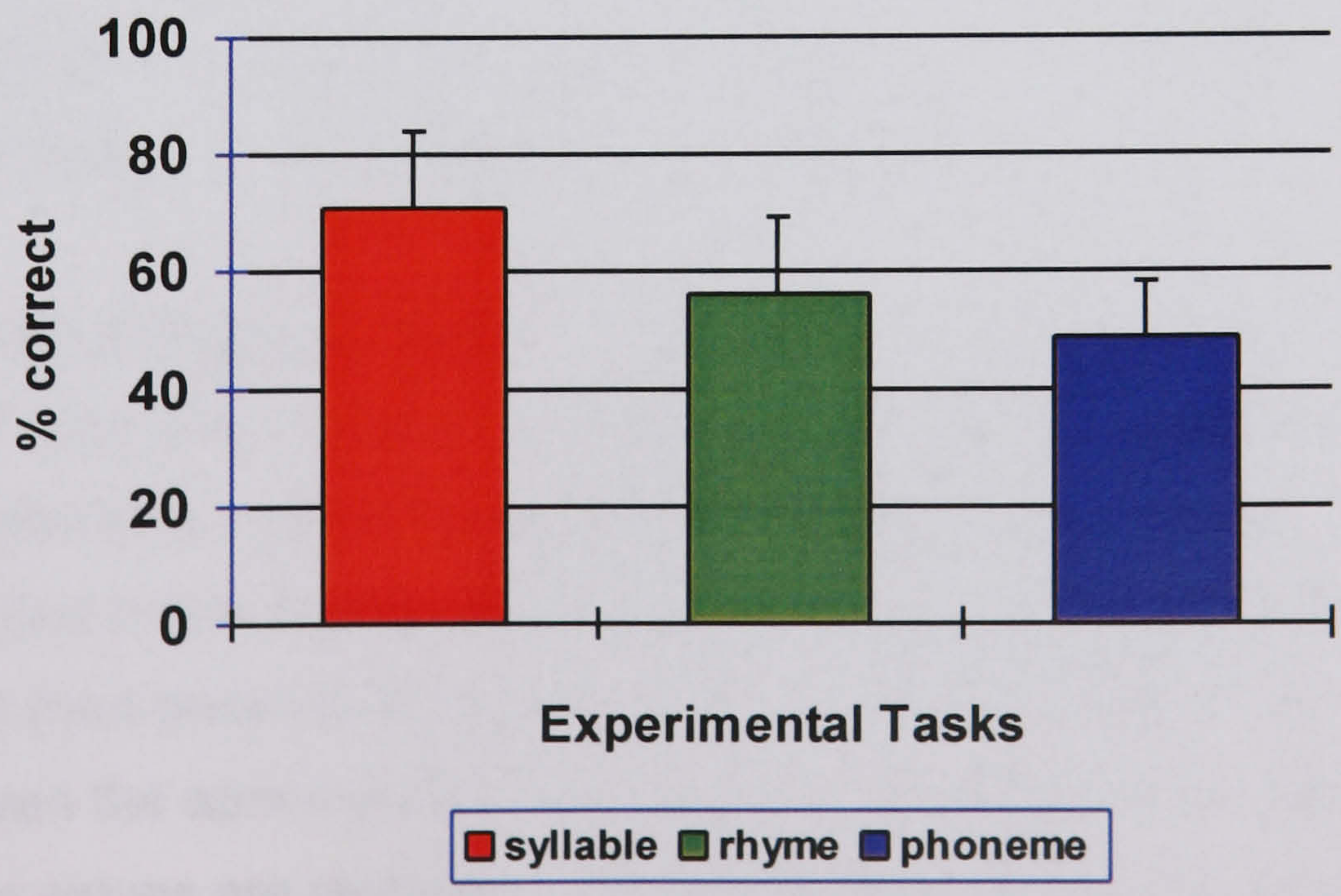
cue	target	distracter	distracter
tiger	ten	kite	lion
fence	fish	peg	gate
black	bin	hat	pink
nail	nurse	zip	pin

5.3 RESULTS

5.3.i Is there an effect of linguistic unit on phonological judgements in children with cochlear implants?

The results from the three experimental measures for the CI group are shown in figure 5.4 (y-bars represent the confidence interval).

Figure 5.4 - CI Group Results



There was a high degree of variability in performance on all the experimental tasks. Inspection of the histograms showed that the data were not normally distributed for all tasks. There was a bimodal distribution and a slight negative skew on the syllable task. The data on the rhyme task were normally distributed. There was some evidence of a bimodal distribution on the phoneme task. Box-plots showed that there were no outliers on any experimental task.

Testing Against Chance

On all experimental tasks, a performance level of 33.3% would be expected by random guessing alone. An analysis of performance against chance was performed. The observed group means were evaluated against the theoretical chance level mean of 33.3%. The z score represents the degree to which the observed mean differs from the theoretical mean (ie. 33.3%). Observed means for the syllable and rhyme tasks were significantly different from scores which would be expected due to random guessing, but the same was not true for the phoneme task.

	% Correct Mean (std)	z-score	p
Syllable	70.89 (27.54)	4.14	p=<.001
Rhyme	56.05 (26.41)	2.36	p=<.05
Phoneme	48.63 (20.34)	1.72	ns

The effect of linguistic level

The next step was to investigate whether the observed differences across the experimental tasks was significant. Due to the non-normal distributions of the data on the syllable and phoneme task, the Wilcoxon Sign test (non-parametric) was selected to assess the effect of linguistic unit. Given the apriori predictions about the direction of the differences, 1-tailed p values are reported. The results showed that the syllable task was easier than the rhyme task, z=-2.416; p=<.05. Rhyme performance was better than phoneme performance, but the difference between percentages correct did not reach significance, z=-1.198; p=.231. The difference between syllable and phoneme performance was highly significant, $z=-3.202$; $p<.001$.

Onset level awareness

It was predicted that if phoneme awareness was above chance level, then singleton onset trials would be easier than clustered onset trials. The data from participants who were above chance on the phoneme test was analysed to test this prediction. The related samples Wilcoxon test showed that there was no significant difference between singleton onset trials and clustered onset trials ($z=-.423$). The mean number of errors was the same for both singleton onset trials (5.5 out of 14 trials) and for clustered onset trials (5.09 out of 14 trials).

Summary

Mean performance on the syllable test was higher than mean performance on the rhyme test, which in turn was higher than mean performance on the phoneme tests. Performance on the syllable and rhyme tests was significantly above chance. However, the pattern of significant differences between the tests shows that only performance on the syllable test was significantly different to performance on the Rhyme and phoneme tests. Singleton onset awareness was not any easier than awareness of initial phonemes within clustered onsets. These later findings could be due to a Type II error given the small number of participants and the large amount of variance on each experimental measure. In order to see whether the predicted developmental pattern was representative of the group, individual patterns of performance are now examined. Patterns of performance on the 0- trials alone, arguably are a purer test of PA, this is examined in Chapter 6.

5.3.ii Developmental Pattern – Individual Participants

If performance at one linguistic level is necessary for performance on the next linguistic level, then individual participants may perform above chance level on the antecedent linguistic level (e.g. syllable) and below chance level on the succeeding level (i.e. rhyme). However, individual participants should not be above chance level on the succeeding level (e.g. rhyme) and below chance on the antecedent level (i.e. syllable). Some participants may be above chance on all tasks or unable to do any task.

Due to the different number of trials in each test, the percentage correct required to be significantly above chance varied slightly for each task; 52% or above on the syllable test, 58% or above on the rhyme test and 54% or above on the phoneme test. A pass/fail classification based on whether a score was significantly above chance was carried out for each participant. Individual data showing actual percentage scores and the pass/fail classification is given in table 5.4 (pass =1, fail =0).

table 5.4 - CI Group Pass/Fail Criterion T1

	Syllable		Rhyme		Phoneme	
CIE						
af	1	78	1	63	1	64
bg	1	100	1	88	1	64
bc	1	67	0	33	0	25
tf	1	100	1	79	1	61
ea	0	26	1	58	0	25
ah	1	100	1	88	1	54
aj	1	70	1	96	1	75
rm	0	43	0	17	0	46
mp	0	19	0	33	0	18
CIL						
mm	1	67	0	46	1	61
cb	0	26	0	13	0	32
cc	0	41	0	25	0	25
dj	1	67	0	21	1	64
lp	1	85	1	79	1	71
sg	1	96	1	75	0	21
hm	1	89	1	88	0	46
jm	1	86	0	42	0	29
sa	1	93	1	75	1	79
cl	1	96	0	46	1	64

1=pass (above chance), 0=fail (not significantly different to chance)

Overall, 15 out of the 19 participants' pattern across the three experimental tasks conformed with one of the predicted patterns. The patterns that conform to developmental predictions are given below:

Syllable	Rhyme	Phoneme	
1	1	1	(af, bg, tf, ah, aj, lp, sa)
1	1	0	(sg, hm,)
1	0	0	(bc, jm)
0	0	0	(rm, mp)

Four participants' had performance patterns which did not concur with developmental predictions;

Syllable	Rhyme	Phoneme	
1	0	1	(mm, dj, cl)
0	0	1	(no participant had this pattern)
0	1	0	(ea)

The pattern of 'mm', 'dj' and 'cl' suggests that phoneme awareness could develop without intra-syllabic awareness. It is plausible that this result is due to the recruitment of orthographic knowledge rather than reflecting true phonological awareness. (See Chapter 6 where the effect of orthography on phonological awareness is explored). The developmental hypothesis would predict that phoneme awareness in these participants would be limited without intra-syllabic awareness. The longitudinal prediction for these children would be a plateau in phoneme awareness if no increase in rhyme awareness occurred.

Summary – Individual Patterns

Overall, the data from individual participants supports the developmental hypothesis. However, four participants had patterns of performance that did not fit the hypothesis.

5.3.iii Response times

The means show that the syllable task was easier than the rhyme task, and the rhyme task was easier than the phoneme task. If the pattern of significant differences is true, indicating that there was no real difference between the rhyme and phoneme tasks, then response times for correct syllable judgements should be quicker than response times for correct rhyme judgements, which should be equal to response times for correct phoneme judgements. If, however, the developmental hypothesis is correct, (syllable easier than rhyme, which is easier than phoneme), then the response times should reflect this; with syllable judgements quicker than rhyme judgements and rhyme judgements quicker than phoneme judgements. Of special interest is the response time pattern between the rhyme and phoneme tasks.

Histogram plots showed that the response times were reasonably normally distributed for all experimental tasks. The means and standard deviations are as follows;

	correct response means	**std**
Syllable	5346.6	(3791.18)
Rhyme	3164.7	(2012.44)
Phoneme	4486.1	(2436.26)

The response time data shows that correct syllable judgements task took longer than correct rhyme and phoneme judgements. These differences were explored in a One-way repeated measures ANOVA showed a main effect of linguistic level (syllable, rhyme, phoneme): $F(2,36) = 4.467$; $p<.05$. The difference in response time between the syllable and rhyme task (2181.915) was significant when adjusted for multiple comparisons (p= <.05). The difference in reaction time between the rhyme and phoneme tasks (1321.5.66) was approaching significance when adjusting for multiple comparisons at the 1-tailed level (p=.057). The difference in response time between the syllable and phoneme tasks was not significant.

Summary – Response Time Data

Correct responses on the rhyme task were significantly faster than both correct syllable and phoneme responses. The response time data suggests that rhyme awareness was indeed easier than phoneme awareness. The fact that the correct rhyme responses were quicker than correct syllable judgements suggests that there was a speed/accuracy trade off in the syllable task. Observation of participants' behaviour during testing supports this view; the majority of participants who were successful on this task either clapped out the syllables in the words or repeated the words to themselves before a judgement was made. This strategy was time consuming, but very successful. In contrast, there was no overt strategy linked to successful performance on the Rhyme and phoneme tasks.

Linguistic Level & PA in CI Participants

The basic pattern of findings when group data, individual data and response times are considered supports the predicted developmental pattern of syllable judgements being easier than rhyme judgements and rhyme judgements being easier than phoneme judgements. Contrary to the prediction, no difference was found between onsets and phonemes in those participants who were above chance on the phoneme task.

5.3.iv Is there an effect of age of fitting with a cochlear implant on PA?

It was predicted that the participants fitted earlier with implants (CIE) would have superior performance on the PA tasks compared to the participants fitted later (CIL). In chapter 4, it was shown that the two groups differed significantly on chronological age and duration of fit with the implant. These factors could also be related to phonological awareness. Reading level may be related to phonological awareness, if deaf children use orthographic knowledge to aid performance. The age equivalent scores from the word decoding test for the two groups are given below:

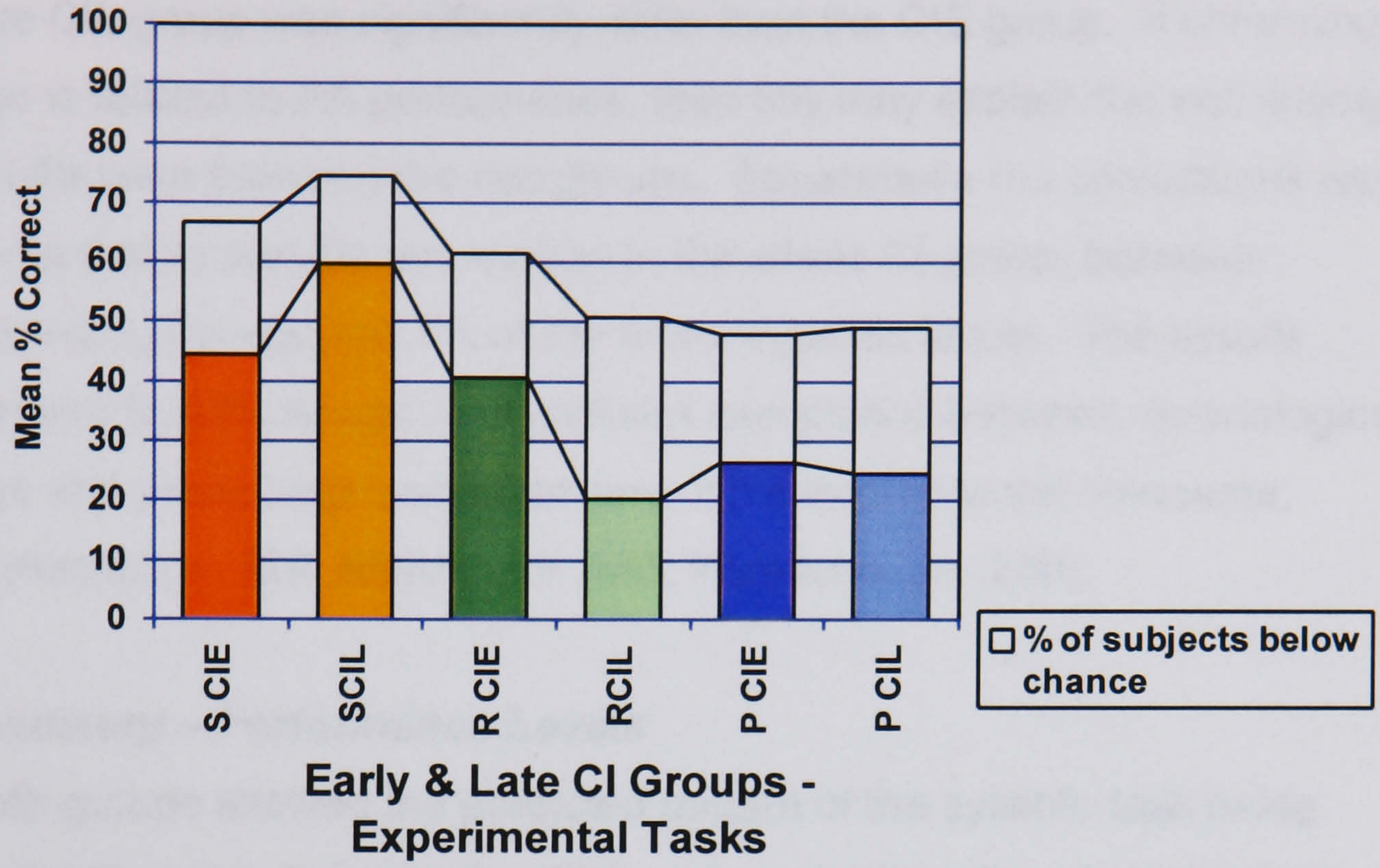
	T1 Word Decoding AE	T2 Word Decoding AE
CIE	6.92 (1.47)	7.44 (1.47)
CIL	6.95 (1.23)	7.36 (1.48)

The actual reading ages of the two groups were equivalent at T1 and T2. Therefore, any differences found on the PA tasks between the two groups, cannot be attributable to a difference in reading age.

PA Performance CIE and CIL

The mean correct responses for each group are shown in figure 5.5 by the total height of the bars. The white portion of the bars represents the proportion of participants within each group who were below chance level on the task (it is not the actual percentage). Both groups followed the predicted pattern of syllable being easier than rhyme, which was easier than the phoneme task. The means and standard deviations for each group are given below;

	Syllable	**Rhyme**	**Phoneme**
CIE	66.78 (31.74)	61.67 (28.55)	48 (20.64)
CIL	75.60 (24.28)	51 (26.78)	49.20 (21.18)



CIE and CIL comparison against chance

The group means for the PA measures were compared to chance. Both groups were significantly above chance on the syllable task (CIE z=3.69; p=<.001, CIL z=4.55; p=<.001). On the rhyme task, only the Early group's mean was significantly different to chance, z=2.94; p=<.01 (CIL z=1.84; ns). Neither group were significantly above chance on the phoneme task (CIE z=1.65, CIL z=1.78). The difference in group means, relative to chance, on the rhyme task is also reflected in the number of participants within each group who were above chance level (see Figure 5.5, the coloured portions of the bars).

Tests for Differences in PA Performance

Since sample sizes were small and unequal, and data were not normally distributed, a series of Mann Whitney U tests were performed to test the possible significance of performance difference between the CIE and CIL groups. The percentage correct was the dependent variable. There was no significant difference in ranks between the CIE and CIL groups on any of the experimental measures; syllable task (U = 43, z = -.164), rhyme task (U = 33.5, z -.942), phoneme task (U = 41, z = -.329).

Controlling for Chronological Age

The CIL group was significantly older than the CIE group. If chronological age is related to PA performance, then this may explain the null finding of a difference between the two groups. Spearman's rho correlations were computed to test the association in the whole CI group, between chronological age and PA at the three linguistic levels. The results showed that there was no significant association between chronological age and percentage correct on any of the experimental measures; (Syllable; $\underline{r}$ = .129, Rhyme; $\underline{r}$ = .145, Phoneme; $\underline{r}$ = .230).

Summary – Performance Levels

Both groups showed the predicted pattern of the syllable task being easier than the rhyme task, which was easier than the phoneme task. There was no significant difference in performance levels between the two groups. There was a 20% difference in performance on the Rhyme task which was not significant but was in the predicted direction (CIE>CIL). When performance against chance was tested the Early group was significantly above chance on the rhyme task, but the Late group was not. More participants performed above chance on the rhyme task in the CIE group than in the CIL group. These two findings suggest that there was a trend towards a potentially significant difference in rhyme awareness between the two groups.

In Chapter 4, we found that three children who were fitted late with cochlear implants had developed spoken language using conventional hearing aids. These children are different to the rest of the CI group, none of whom had developed a significant amount of spoken language using conventional hearing aids. Inspection of table 5.4 shows that at T1, these three participants 'sg', 'lp' and 'hm' had performance on the rhyme task which was above chance level. There was only one other child in the CIL group ('sa') who had rhyme awareness above chance at T1, but in the CIE group six participants were above chance. Mann Whitney tests were computed, excluding 'sg', 'lp' and 'hm', to test the difference between the CIE and CIL groups at T1. The results showed that there was no significant difference between the CIE and CIL groups on the syllable and phoneme tasks. The difference on the rhyme task, at T1, was approaching significance at the 1-tailed level ($U = 16$, $z = -1.64$; $p = .057$). This suggests that the early fitting of an implant may benefit phonological awareness of rhymes, in children who were not gaining any functional benefit from conventional hearing aids.

However, the difference in rhyme awareness between the CIE and CIL groups could have been due to the difference in duration of fit, which differed significantly between the groups. However, if duration of fit was the critical factor, then syllable and phoneme levels should also have differed.

5.3.v Relationship between Duration of Fit and The Rhyme Task

In order to test the effect of duration of fit on performance levels in the rhyme task, a Spearman's rho correlation was computed. The correlation between duration of fit and percentage of correct responses on the rhyme task was not significant ($\underline{r} = .387$).

In order to be sure that the groups did not differ with regard to the impact of duration of fit on experimental task performance, scatter grams were plotted (shown in Appendix B). The CIE and CIL groups were plotted separately. When duration of fit was plotted against the rhyme measure, a difference was noticeable between the two groups. There was a flat regression function for the CIL group, but a positive regression line for the CIE group. As duration of fit increased in the CIE Group, performance on the rhyme task also increased, but this did not seem to be true for the CIL group. A Spearman's Rho correlation was computed for the CIE group, to assess the significance of the observed relationship. The results showed a significant correlation between duration of fit and rhyme performance at the 1 tailed level, (r = .633, p=<.05).

Tests for Differences in Reaction Times

Inspection of the response time data may reveal a significant difference between the groups that was not found for mean performance levels. The CIL group were significantly older than the CIE group, therefore, they are predicted to have faster response times for correct judgements. Mean response times are given below;

	Syllable	Rhyme	Phoneme
CIE	6000	3700	5900
CIL	4800	2700	3200

Both groups had longest response times for correct responses on the syllable task and fastest response times for correct responses on the rhyme task. To test the significance of the observed differences whilst controlling for chronological age, a repeated measures Anova was computed. Response time for correct judgements at the three linguistic levels (syllable, rhyme, phoneme) was the within-subjects factor, group was the between-subjects factor and chronological age was the covariate. The results showed that there was no main effect of linguistic level ($F(2,32) = 1.06$) and no main effect of group ($F(1,16) = .013$). There was no significant interaction between chronological age and linguistic level ($F(2,32) = .670$) and no significant interaction between group and linguistic level ($F(2,32) = .831$). There was a main effect of chronological age at the one tailed level ($F(1,16) = 4.05$, $p<.05$).

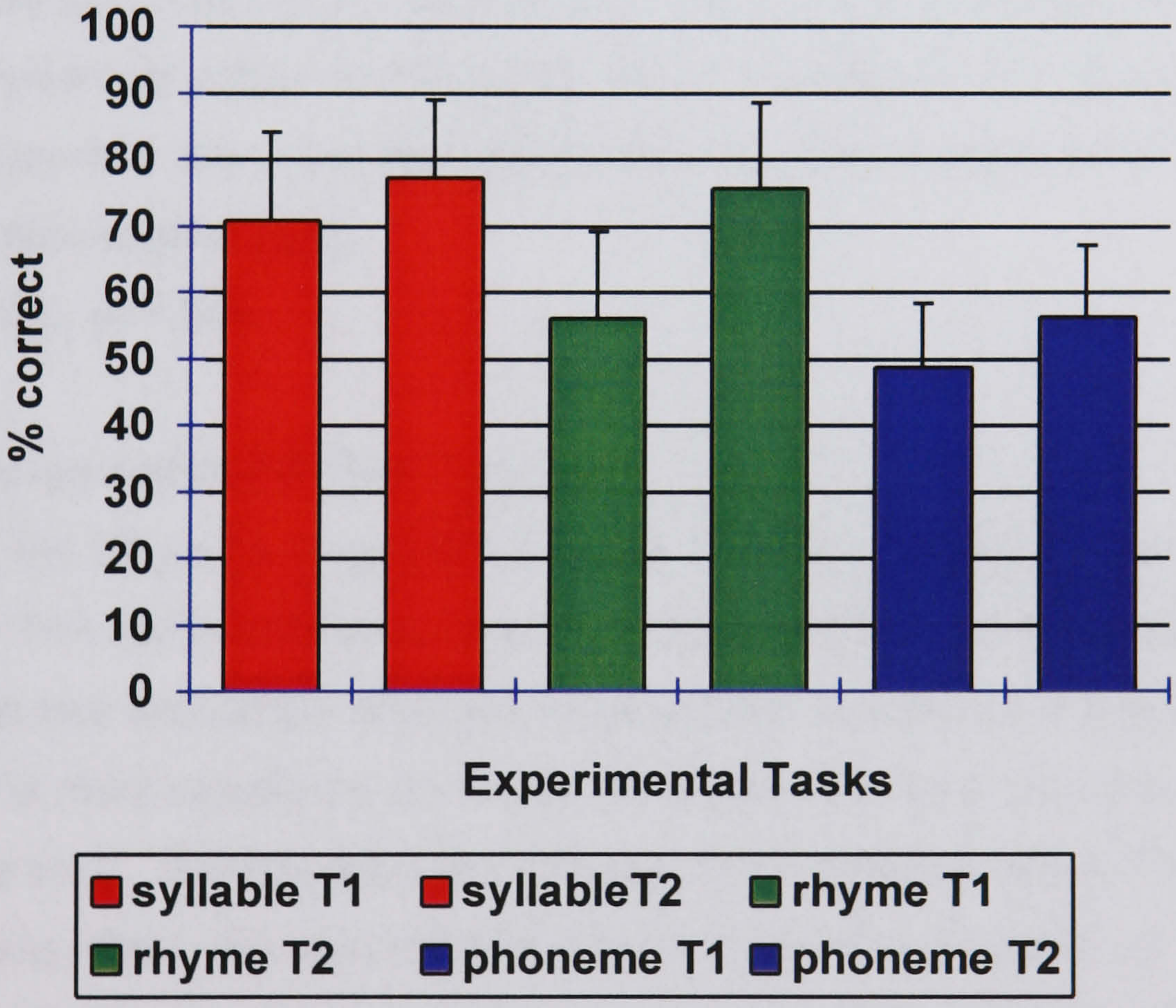
Summary – Response Times

Both groups showed the same pattern of response times, taking longer to make correct syllable judgements than either rhyme or phoneme judgements. Correct rhyme judgements were quickest for both groups. Despite the fact that chronological age was related to speed for correct responses, the CIL group, who were significantly older than the CIE group, did not have significantly faster responses for correct judgements.

5.3.vi What is the developmental pattern of PA in children with cochlear implants?

Figure 5.6 shows the results of T2 testing in relation to performance at T1 (y-bars represent the confidence interval). There was an improvement over time at all linguistic levels.

Figure 5.6 - T1 - T2 CIE & CIL



Inspection of the histograms showed that the data at T2 were not normally distributed. There was evidence of bi-modal distribution on both the syllable and phoneme tasks and ceiling effects on the syllable and rhyme tasks. Box plots showed no outliers on any of the experimental tasks. The means from T1 and T2 testing are shown below (standard deviations in brackets);

	% Correct Mean T1	% Correct Mean T2
Syllable	71.19 (27.54)	77.3 (23.45)
Rhyme	56.35 (26.41)	75.7 (25.97)
Phoneme	48.63 (20.34)	56.3 (21.99)

Longitudinal Correlation of PA Measures

If the experimental tasks are reliable, then highly significant correlations should be found across time for the same task, although floor performance at T1 on the phoneme task is expected to mask correlational relationships on this task. Spearman's rho correlation over time on the syllable task was highly significant ($\underline{r}$ =.707, p=<.01) as was the correlation over time on the rhyme task ($\underline{r}$ =.808, p=<.01). Correlation on the phoneme task, reached significance, but was weaker than the other two experimental tasks
($\underline{r}$ = .434, p=<.05).

Improvement in PA Over Time

At T1 the CI group mean on the rhyme task was only just above chance level. Phoneme awareness was not above chance. Since intra-syllabic awareness should develop before phonemic awareness it was predicted that the most significant improvement found over time would be on the rhyme task. The negative skew found on the syllable test at T1 indicated a ceiling effect, this was expected to confound the detection of improvement in syllable awareness over time. The Wilcoxon test for related samples test was used. The difference in performance over time on the syllable test was not significant (z = -.955). The difference in performance on the rhyme test was highly significant (z = -3.304; p=<.001). On the phoneme task the difference between performance at T1 and T2 did not reach significance (z = -1.198).

If the pattern of significant improvement over time is correct (i.e. only rhyme awareness was significantly better at T2), then the proportion of participants moving from below chance at T1 and above at T2 should be greater for the rhyme task than any of the other tasks.

Syllable task:	4 participants were below chance at T1 2 of those participants were above chance at T2 representing 50%
Rhyme task:	8 participants were below chance at T1 4 of those participants were above chance at T2 representing 50%
Phoneme task:	8 participants were below chance at T1 1 of those participants was above chance at T2 representing 12.5%

The proportion of participants moving from below to above chance was the same for the syllable and rhyme tasks. This supports the view that real improvement over time on the syllable task did take place, but was masked by ceiling effects.

The longitudinal developmental pattern of PA

If the developmental hypothesis is correct, then an antecedent linguistic level at T1 should correlate with the subsequent linguistic level at T2. So, syllable performance at T1 should be related to rhyme performance at T2, rhyme at T1 should be related to phoneme performance at T2 and syllable performance at T1 should be related to phoneme performance at T2. Non-parametric, time-lagged Spearman's rho correlations were computed to investigate this prediction.

Syllable at T1 related to Rhyme at T2	$r = .528$, $p=<.05$
Rhyme at T1 related to Phoneme at T2	$r = .485$, $p=<.05$
Syllable at T1 related to Phoneme at T2	$r = .593$, $p=<.01$

Summary – Developmental Hypothesis Longitudinal Data

It was predicted that intra-syllabic awareness would precede phoneme awareness and therefore, most improvement was predicted for the measure of rhyme awareness. There was improvement over time on all the experimental measures. The only significant difference over time was on the rhyme test. We also found that there was a relationship between performance on antecedent linguistic levels at T1 and subsequent linguistic levels at T2. These findings support the developmental hypothesis.

5.3.vii Effect of Early fitting with CI on development of PA at T2

Table 5.5 shows means from T1 and T2 for the CIE and CIL groups respectively, the associated z-scores for tests against chance and the proportion of participants above chance.

table 5.5 – T1/T2 CIE and CIL means & chance analysis

		means (z score)		**% sbjcts > chance**	
		T1	**T2**	**T1**	**T2**
Syllable task					
CIE	n=9	66.78 (3.69***)	69 (3.93***)	66.7	66.7
CIL	n=10 (T1) n= 9 (T2)	75.60 (4.55***)	85.56 (5.76***)	80	100
Rhyme task					
CIE	n=9	61.67 (2.94**)	80.56 (5.58***)	66.7	87
CIL	n=10 (T1) n= 9 (T2)	51 (1.84)	70.89 (3.90***)	40	70
Phoneme task					
CIE	n=9	48 (1.65)	56.33 (2.58**)	55	55
CIL	n=10 (T1) n= 9 (T2)	49.2 (1.78)	56.33 (2.58**)	50	66

*p<.05, **p<.01, ***p<.001

The results show that at T2 the CIE group was above chance on the phoneme task and the CIL group was above chance on the rhyme task and on the phoneme task. Thus, by T2 the groups were above chance on all the PA tasks.

Test for Group Differences in Performance in PA at T2

Mann-Whitney tests were computed to see whether the differences between the groups were significant. The results showed that performance levels did not differ significantly between the groups on any experimental measure; syllable task ($U = 23$, $z = -.473$), rhyme task ($U = 17.5$, $z = -1.159$), phoneme task ($U = 24.5$, $z = -.296$).

Duration of Fit and Rhyme Awareness at T2

At T1, a correlation between duration of fit and performance on the rhyme task was found, but only for the CIE group. The fact that no correlation was found in the CIL group was probably due to the fact that they were not above chance level on the rhyme test at T1. At T2 the CIL group mean was significantly different to chance. Therefore, if duration of fit is related to rhyme awareness in the CIL group, then a correlation should be found.

In order to test the relationship between duration of fit and rhyme awareness at T2, Spearman's rho correlations were computed. The results showed a non significant relationship between duration of fit and rhyme performance at T2 ($\underline{r} = .383$). Separate correlations for each group (CIE and CIL) were computed, the results showed no relationship between duration of fit and rhyme performance for either group. Failure to find a correlation for the CIE group could have been due to ceiling performance on the rhyme task at T2. The data were plotted on scatter grams (see Appendix C), which indicated that duration of fit was related to performance in the Early group, but, as suggested, ceiling performance masked the correlation. The same was not true for the CIL group, even though performance on the rhyme task at T2 was above chance, the regression line between the two variables was flat. It seems that duration of fit is related to increased rhyme awareness, but only for the Early group.

Summary – Group Differences in PA at T2

There were no significant differences in phonological awareness between the two groups at T2. At T2, the CIL group's duration of fit was 4 years 1 month (std .65). This is a similar to the CIE group at T1, which was 4 year 7 months (std .84). At T2, the CIL group's mean on the rhyme task was essentially equivalent to the CIE group at T1. This indicates that duration of fit was associated with rhyme awareness, although correlations between duration of fit and rhyme performance at T2 were not significant.

5.4 DISCUSSION

Is there an effect of linguistic unit on phonological judgements in children with CIs?

It was predicted that CI participants would find syllable judgements easier than rhyme judgements, which would be easier than phoneme judgements. This pattern was found at both T1 and T2.

The response time data and behavioural observation suggested that greater cognitive effort was needed to be successful on the syllable task compared to the rhyme task. It is likely that this is due to the 1-to-1 correspondence skills required in the syllable task. Some research evidence which supports this explanation comes from a comparison of Liberman et al's (1974) syllable tapping task and Treiman et al's (1991) shared syllable segment task. Only Liberman's tapping task required 1-to-1correspondence. A comparison of the raw scores achieved by participants of comparable ages and educational grades showed that participants made more errors on the tapping task compared to the shared segment task.

On the phoneme task at T1, neither of the CI groups' performance was significantly different to chance. It is of interest that the CIL group's increased age did not lead to elevated performance on this task. The two groups had equivalent reading ages, but the CIL group had longer exposure to print. This might have been expected to give them an advantage on the phoneme task, since learning about graphemes might enhance phoneme awareness. There is a reciprocal relationship between reading and phonemic awareness in hearing children and adults.

Participants who were above chance on the phoneme task showed no enhanced performance for singleton onset trials versus clustered onset trials at either T1 or T2. This may reflect the fact that phoneme awareness was based largely on orthographic knowledge, meaning that the phonological ease of singleton trials over clustered trials was not relevant to the CI participants, if decisions were primarily based on an orthographic judgement. This possibility is explored further in Chapter 6.

What is the developmental pattern of phonological awareness in children with cochlear implants?

Longitudinal testing showed improvement over time on all measures of phonological awareness. The most significant improvements were on the syllable and rhyme tasks. There was a relationship between antecedent linguistic levels at T1 and subsequent linguistic levels at T2, which supports the developmental hypothesis.

Overall, the results indicate that in deaf children with cochlear implants, awareness of speech units develops first at the level of the syllable then at the intra-syllabic level. Awareness of phonemes is the most difficult level, but does develop over time. Between T1 and T2, the most significant development of PA occurred at the level of intra-syllabic (rhyme) awareness. One possibility is that the language development of the children when they were tested was best able to support rhyme awareness. In hearing children, rhyme awareness is evident at around the age of 3 to 4 years. At T1, the receptive vocabulary age of the whole CI group was 4 years 2 months, although there was a wide range in age equivalent scores (2 years – 7 years 5 months). The findings suggest that phonological awareness is related to language development in deaf children with cochlear implants.

Is there an effect of age of fitting on PA?

There were no significant differences on PA measures at T1 or T2 between the two groups. It was predicted that the early fitting of an implant would enhance PA and therefore, superior performance on the PA tasks was predicted for the participants fitted early. A 20% difference on the rhyme task was observed between the groups at T1 and further, the CIE group was above chance and the CIL group were not. This difference is likely to be due to the length of time participants had been using their implant. Duration of implant use for the CIL children at T2 was similar to that of the CIE children at T1. Rhyme performance of the CIL group at T2 was equivalent to rhyme awareness of the CIE group at T1.

In the next chapter the benefit of CI on PA skills is explored by comparing the CI group with deaf children making good use of conventional hearing aids. A comparison of PA performance will also be made between the CI group and hearing children matched for reading level and chronological age.

Chapter 6 – The Benefit of CI on Phonological Awareness

6.1 INTRODUCTION

It has been shown that phonological awareness in deaf children with cochlear implants follows the same developmental path as that of hearing children. The aim of this chapter is to explore the benefits of CI on phonological awareness by comparing the CI group with deaf children wearing hearing aids and hearing children matched for reading level and chronological age.

In Chapter 3, research was reviewed which suggests that demonstrable benefits in speech perception and the rate of spoken language development are derived through the use of a cochlear implant. In 1998 when this study began the comparison groups were other profoundly deaf children who used conventional acoustical or tactile hearing aids. The benchmark comparison groups have since changed (see Chapter 3, Section 3.3). However, at the start of this study the benchmark group was children with hearing impairments in the region of 90 to 100 dB HL who were making good use of conventional acoustical hearing aids (so called 'gold hearing aid users'). Whilst this calculation is based on American pure tone calculations, the definition, 'gold hearing aid user' also encompassed broader factors such as the use of the hearing aid and the functional attainments of the child. When this project began it was customary (regardless of the country of origin of the research) to infer a benefit of CI if the CI group was equivalent to a group of 'gold hearing aid users'. More recent studies have shown that some children with cochlear implants can have the same speech perception ability as children who are severely deaf (see Chapter 3, Section 3.4). Therefore, in this study the performance of the CI group was compared to two groups of deaf children using hearing aids; a group with profound hearing loss (i.e. average pure tone thresholds to .5 kHz, 1kHz, 2kHz, 4kHz over 95 dB HL) and a group with severe hearing impairment (i.e. average pure tone thresholds between 71 and 95 db HL).

By choosing comparison groups based on degree of residual hearing the rationale in the CI research literature has been that outcome post implant fitting is solely due to the improved auditory perception afforded through the implant. However, ideally any comparison group of deaf children should be matched for quality and quantity of rehabilitation. In the UK, it is not possible to find a group of deaf children with hearing aids who have benefited from the same specialist longitudinal assessment as children with cochlear implants. It is important to acknowledge that any benefits of cochlear implant may not be due **solely** to the implant itself and the increased auditory capacity afforded thereby, but likely reflect the whole CI package.

Previous research on the phonological awareness skills of deaf children typically includes hearing comparison groups. A comparison with chronological age matched controls (CA controls) reveals the extent to which phonological awareness is delayed relative to hearing children of the same age. We have seen from the literature reviewed in Chapter 2 that phonological awareness is almost always delayed in deaf children when compared to hearing children of the same age. However, Sterne and Goswami (2000) showed that awareness of syllables was at the same level as CA controls and Charlier and Leybaert (2000) found age appropriate rhyme awareness in a small sub-group of very young deaf children. Some of the studies reviewed in Chapter 2 adopted a reading level matched design. The rationale for including a group of children matched on reading level is to establish the extent to which phonological skill is related to reading in deaf children. The existing literature shows that even when compared to younger hearing children who are at the same reading level (RL controls), deaf children's phonological awareness is delayed (with the one exceptional finding on syllable awareness from

Sterne & Goswami, 2000). The finding of a significant delay in rhyme awareness in deaf children compared to RL controls suggests that phonological awareness plays a less significant part in determining reading success in deaf children than it does in hearing children.

There have been no previous studies of phonological awareness in children with cochlear implants. If CI use benefits phonological awareness to a similar magnitude as the reported gains in speech perception then PA in the CI group is predicted to be at least equivalent to the profoundly deaf hearing aid users. Based on the previous PA literature in deaf children rhyme and phoneme awareness is predicted to be significantly delayed in the CI group relative to hearing controls (both RL and CA controls). Based on the findings of Sterne and Goswami (2000), awareness of syllables might be age appropriate. It may be that CI strongly benefits PA so that the CI group is equivalent to a group of severely deaf children. If this is the case then we might expect delays in PA relative to the CA controls and a smaller discrepancy between the CI group and the younger RL controls. It is difficult to predict the exact extent of the delay based on the previous PA literature because studies of PA with deaf children using hearing aids sometimes provide insufficient audiological information (i.e. degree of residual hearing, the age of onset of deafness) or profoundly and severely deaf children have been grouped together. Overall, a developmental pattern of delay is predicted relative to hearing children, so, syllable awareness should be less delayed than rhyme awareness and phoneme awareness will be most delayed. Furthermore, PA performance in the CI group should be less delayed when compared to younger RL controls than the CA controls.

<u>Research Questions</u>

1. **Does CI benefit phonological awareness – comparison with deaf children with hearing aids?**

   If CI benefits phonological awareness in deaf children, then the CI group's performance should be equivalent to a group of profoundly deaf children making good use of residual hearing with hearing aids. A strong benefit of CI on phonological awareness would be shown if the CI group were at an equivalent level to a group of severely deaf children with hearing aids.

2. **Does CI benefit phonological awareness – comparison with hearing children?**

   If CI benefits PA so that the CI group is equivalent to a group of profoundly deaf children then based on the previous literature, the following predictions are made;

   syllable awareness will be at least equivalent to RL controls,
   rhyme awareness will be delayed compared to RL and CA controls
   phoneme awareness will be significantly delayed compared to RL and CA controls.

6.2 METHOD

6.2.i Participants

Deaf Children

The participants fitted with cochlear implants are the same group of participants presented in Chapter 4.

In order for deaf children with hearing aids to be as comparable as possible to the CI group, a strict selection criteria for inclusion in the study was imposed. Deaf children with hearing aids were not matched on a single measure of pure tone threshold. Instead, the focus was on including children who were comparable to the CI group on a broader range of factors. The following criteria were imposed;

- congenital profound or severe deafness
- no general learning difficulties
- English the first and only oral language
- good users of hearing aids, both in terms of quality and quantity

The sample of deaf children with hearing aids was obtained through a number of ways. The preferred method of recruitment for the hearing aid users was in schools where the CI participants were placed. This was an attempt to control the instructional approach and rehabilitative factors between CI and hearing aid users. Unfortunately, it was not possible to recruit enough children through this method so participants were recruited through other contacts. The Department for Audiological Medicine at Great Ormond Street Hospital identified a small number of children who fitted the criteria. The rest of the sample was obtained by contacting teachers of the deaf (in units and peripatetic services) in the South East and South West of England. In total 22 children were identified who fulfilled the criteria. Written information and consent forms were sent to the carers of these children. Positive consent was received from 21 of them.

A group of 11 profoundly deaf children with hearing aids (PHA) and a group of 10 severely deaf children with hearing aids (SHA) participated in the study. Ten of the profoundly deaf children were in placed in units for deaf children within mainstream schools and 1 child was being supported in mainstream school. Seven of the severely deaf children were in units and 3 children were in mainstream school. Of the total 21 children with hearing aids, 8 children in the PHA group were in the same units as the CI participants.

table 6.1 – Participant Summary CI, PHA and SHA Groups

Group		CA		Gender		Matrices Non-verbal reasoning t-score		Unaided PTA Mean	
CI	n=19	8.36	(1.24)	10 male	9 female	55.63	(13.98)	114.3	(8.21)
PHA	n=11	9.4	(.98)	3 male	8 female	54	(9.71)	106.7	(5.54)
SHA	n=10	7.37	(1.17)	4 male	6 female	60.30	(8.53)	77.8	(8.67)

standard deviations in brackets

The differences in chronological age between the groups, at the time of testing was not significant, neither was there any significant difference in Matrices, non-verbal reasoning. The unaided pure tone threshold calculation is the mean response to pure tones at; 500 Hz 1000 Hz, 2000 Hz and 4000 Hz in the better ear. For the CI group, the unaided pure tone threshold was taken from clinical files at the implant centre, this measure was only available prior to implant fitting. For the other deaf children, the calculation was based on the results of the child's most recent audiogram. The PHA group had a mean pure tone threshold that was lower than the CI group (indicating more residual hearing).

Hearing Children

Hearing children were recruited from a school in South East London. Two groups were formed. One group was matched for reading age to the CI group (RL group). This was achieved using the BAS Word Reading test. One group was matched for chronological age to the CI group (CA group). A selection criteria was imposed for all hearing participants;

- reading skills within the normal range
- no history of special needs
- no known history of hearing difficulties

In line with the school policy, carers were informed of the project via the school. Consent was obtained by asking parents to inform the school if the did not wish their child to be included in the study. The summary of hearing children is given in table 6.2

table 6.2 Participant Summary, CI, RL and CA Groups

Group		CA	Gender	Matrices Non-verbal reasoning t-score
CI	*n=19*	*8.36 (1.24)*	*10 male 9 female*	*55.63 (13.98)*
RL	n=19	6.75 (.58)	8 male 11 female	50.37 (.58)
CA	n=19	8.38 (1.19)	9 male 10 female	52.42 (11.93)

standard deviations in brackets

Table 6.2 shows that the non-verbal reasoning skill of the hearing groups was roughly equivalent to the CI group. Independent t-tests confirmed that there was no significant difference in BAS Matrices, between the CI and RL controls (t = 1.358) and the CI and CA controls (t = .762).

6.2.ii Measures and Procedures

The experimental measures of PA have been described in Chapter 5. All participants completed all three experimental tasks. Two participants in the SHA group did not complete the phoneme task; one due to attention difficulties and the other due to illness on the last day of the school year.

The British Picture Vocabulary Scales and Word Reading Test were administered to the deaf children with hearing aids with exactly the same modifications to administration as described for the CI group, in Chapter

4. These two measures were administered to the hearing children according to published instructions.

The BPVS age equivalent scores and BAS Word Reading age equivalent scores for the groups are given below;

table 6.3 Vocabulary & Reading Age

Group		BPVS Age		Word Reading Age	
CI	n=19	4.15	(1.56)	7.08	(1.31)
PHA	n=11	4.55	(1.88)	7.08	(1.07)
SHA	n=10	5.30	(1.63)	7.07	(1.44)
RL	n=19	6.51	(1.16)	7.08	(1.10)
CA	n=19	8.64	(2.35)	9.32	(2.17)

standard deviations in brackets

CI, PHA and SHA Groups

There was no significant difference in BPVS age between the PHA and the CI group ($U = 93$, $z = -.496$). The difference in BPVS age between the SHA and the CI group was approaching significance ($U = 57$, $z = -1.746$; p .084). Word reading age was equivalent in the three groups of deaf children.

CI, RL and CA Groups

The CI group had significantly lower receptive vocabulary age compared to the RL controls ($t = -5.303$, $p<.001$) and compared to the CA controls ($t = 06.940$, $p<.001$). By design there was no difference in reading age between the CI group and the RL controls, but the CI group had significantly lower word reading skills compared to the CA controls ($t = -3.998$, $p<.001$).

6.3 RESULTS

6.3.i Does CI benefit PA? – Comparison with Deaf Hearing Aid Users

The experimental hypothesis of this thesis is that the fitting of a CI will enhance phonological awareness in deaf children due to the increased access to speech that the implant affords. If CI benefits phonological awareness, then the CI group's performance should be equivalent to a group of less profoundly deaf children who are making good use of residual hearing with hearing aids (PHA). If the CI group's performance is equivalent to a group of deaf children who are severely deaf with hearing aids (SHA), this would demonstrate an even stronger benefit of CI. If auditory perceptual level influences PA then the following rank in performance on the PA tasks is predicted;

SHA	1st
PHA = CI	2nd

If CI **strongly** benefits PA then the CI group should be equivalent in performance to the SHA group and the PHA group should be the lowest rank.

Performance Levels

The performance means for the three groups are given in table 6.4. Figure 6.1 shows the performance of the three groups (CI, PHA, SHA) across all the experimental tasks (Syllable, Rhyme, Phoneme). The height of the bars is the actual group mean and the white portion of the bars represents the proportion of participants scoring below chance in each group (it is not the actual percentage). Figure 6.1 shows that the SHA group is ranked highest on each linguistic level, with most marked differences between the SHA and the other two groups on the rhyme and phoneme tasks. The performance of the CI and PHA group is broadly equivalent. On the syllable task (the 3 orange bars), the majority of participants in all groups scored above chance and all the group **means** are well above the level expected by chance alone. Results from the rhyme task (the 3 green bars) show larger differences between groups. The SHA found this task the easiest, 90% of participants in the SHA group scored above chance, in contrast to the other two groups where around 50% of participants were above chance. The superior performance of the SHA group is also marked in the phoneme task (the 3 blue bars) both in terms of overall performance and in the percentage of participants above chance level.

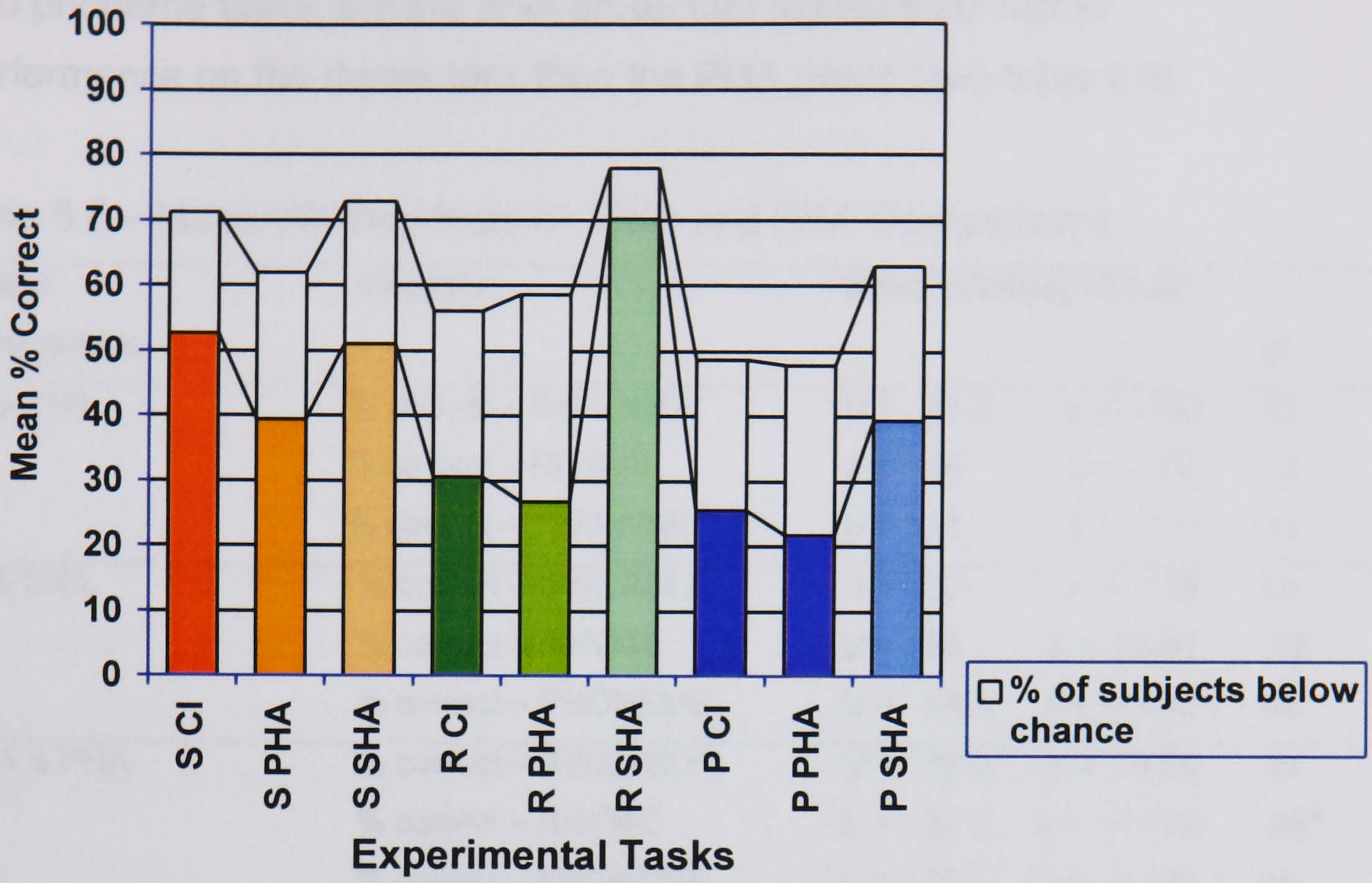
table 6.4 – PA Performance – Mean % Correct

Group	Syllable	Rhyme	Phoneme
CI n=19	70.89* (27.54)	56.05* (26.41)	48.63 (20.34)
PHA n=11	61.91* (25.77)	58.65* (25.23)	49.20 (22.32)
SHA n=10	72.80* (25.60)	77.90* (22.22)	63* (20.35)

*significantly above chance

standard deviations in brackets

Figure 6.1 - CI, PHA & SHA Groups PA Tests



Test of Group Differences in PA Performance

If CI benefits PA, then there should be no significant difference between the CI group and the PHA group. If CI strongly benefits PA, then there should be no significant difference between the CI group and the SHA group. If auditory perceptual level influences PA, then there should be a significant difference between the SHA group and the PHA group on the PA tasks.

Figure 6.1 indicates that there was no difference between the CI group and the PHA group at any linguistic level. In order to test this, the Mann-Whitney test was used. The results showed that there were no significant differences between the CI group and PHA group on any of the experimental measures (see table 6.5). In order to establish the possible significance of the difference between the SHA group and the CI group on the rhyme and phoneme tasks, Mann-Whitney tests were computed. The results (in table 6.5) showed that the only significant difference between the CI and SHA group was on the rhyme task. There was no significant differences between the SHA and PHA groups on the syllable and phoneme tasks, but the SHA group had significantly higher performance on the rhyme task than the PHA group (see table 6.5).

table 6.5 – Mann-Whitney tests CI, PHA and SHA Comparisons

Group Comparison	Variable	Mann-Whitney U test		p
CI & PHA	% correct – SYLLABLE	U = 81.5	z = -.992	ns
	% correct – RHYME	U = 96	z = -.367	ns
	% correct – PHONEME	U = 101	z = -.151	ns
CI & SHA	% correct – SYLLABLE	U = 82	z = -.138	ns
	% correct – RHYME	U = 50	z = -2.069	.05
	% correct – PHONEME	U = 49.5	z = -1.412	ns
SHA & PHA	% correct – SYLLABLE	U = 39.5	z = -1.099	ns
	% correct – RHYME	U = 32.5	z = --1.790	.05*
	% correct – PHONEME	U = 28	z = -1.323	ns

* significant at 1- tailed level

Summary

The finding that the CI group was as competent as the PHA group on the PA tasks supports the hypothesis that CI benefits phonological awareness. The finding that the CI group was as competent as the SHA group on the syllable task shows that CI strongly benefits awareness of syllables. However, the difference between the SHA group and PHA group on the syllable task was not significant, whereas the difference between these two groups on the rhyme task was significant. This pattern of results suggests that awareness of syllables is not as dependent on auditory perceptual level as awareness of intra-syllabic units.

It was surprising that there was no significant difference between the SHA group and the CI group and PHA group on the phoneme task. Figure 6.1 shows a large difference in group means and the SHA group were the only group whose overall performance on the task was significantly different to chance. One reason why the group comparison failed to reach significance could be the high degree of variability in performance within groups and the relatively small number of participants.

6.3.ii Test for Differences in Reaction Times

Reaction times are a measure of the automaticity or ease with which phonological judgements are made. The results so far show that the CI group had equivalent performance on all the PA tasks to the PHA group. Therefore, if performance levels reflect the phonological processing abilities of the participants, the CI group's reaction time should be equivalent to the PHA group on all the PA tasks and equivalent to the SHA group on the syllable task. The mean response times for correct judgements on the PA tests are given below;

Group		Syllable	Rhyme	Phoneme
CI	n=19	5500 (3800)	3200 (2000)	4500 (2400)
PHA	n=11	6000 (2600)	4500 (2100)	5200 (4600)
SHA	n=10	7400 (7600)	2600 (1800)	5800 (4000)

standard deviations are in brackets

All groups showed the same pattern of response times, correct rhyme judgements were quicker than correct phoneme judgements and correct syllable judgements took longest to make. The CI group had faster RTs than the PHA group at all linguistic levels. The CI group also had faster RTs than the SHA group for correct syllable and phoneme judgements.

Chronological Age

The three groups did not differ significantly in chronological age at the time of testing, but they were not matched for chronological age. It is possible that speed of processing will be related to chronological age and therefore, related to reaction time. In order to test this, Pearsons's correlations were computed between chronological age and reaction time for correct responses for syllable, rhyme and phoneme judgements. The data from all 40 deaf participants was entered. The results showed that chronological age did not correlate with reaction times on any of the PA tasks; (syllable r = .295, rhyme r = .196, phoneme r = .257).

Test for Significance in RTs

In order to test the significance of the observed differences between the groups Mann Whitney tests were computed comparing the RTs for all the experimental measures between the CI and PHA group (see table 6.6). The results showed that there was no significant difference between the two groups on RTs for correct syllable and phoneme judgements. The difference in response times for correct rhyme judgements was significant at the 1-tailed level. The CI group was significantly faster than the PHA group. The results from the Mann Whitney test, comparing the CI group to the SHA group showed that there were no significant differences in reaction times to correct judgements on any of the PA tasks.

table 6.6 Comparison of RTs

Group Comparison	Variable			p
CI & PHA	SYLLABLE RT	U = 81	z = -1.01	ns
	RHYME RT	U = 63	z = -1.79	.05
	PHONEME RT	U = 98	z = -.28	ns
CI & SHA	SYLLABLE RT	U = 90	z = -.23	ns
	RHYME RT	U = 89	z = -.28	ns
	PHONEME RT	U = 64	z = -.64	ns

Summary

The CI group's response time for correct phonological awareness judgements was equivalent to the PHA group at the syllable and phoneme level. The CI group was significantly faster at making correct rhyme judgements than the PHA group. The CI group's response time for correct phonological judgements was equivalent to the SHA group at all linguistic levels. The response time analyses show that the children with cochlear implants were able to make correct phonological judgements with the same speed of response as children who are severely deaf.

6.3.iii Does cochlear implantation benefit phonological awareness? Comparison with hearing children

We have found that the phonological awareness of the CI group is equivalent to a group of profoundly deaf children across the linguistic levels. Awareness of syllables in the CI group was equivalent to a group of severely deaf children. Therefore, we predict the following relative to hearing children;

syllable awareness in the CI group will be at least equivalent to RL controls and may be equivalent to CA controls.

This expectation is based on the previous research findings of Sterne & Goswami (2000) who showed that awareness of syllables in a group of deaf children was equivalent to younger children at the same reading level and not significantly different to hearing children of the same age. However, one problem with this study is the lack of audiological information making it difficult to know how representative their sample is. If syllable awareness in the CI group is equivalent to hearing children of the same chronological age, then this would show a very beneficial effect of CI.

rhyme awareness will be delayed compared to RL and CA controls

All previous research has shown that deaf children's rhyme awareness is significantly delayed compared to reading level matched comparison groups. The results from the comparison with deaf children using hearing aids shows that the CI group's rhyme awareness was similar to the PHA group. Therefore, in the light of the previous research findings, it is unlikely that the CI group's rhyme awareness will be equivalent to hearing children at the same reading level and is expected to be very delayed compared to hearing children of the same chronological age.

phoneme awareness will be significantly delayed compared to RL and CA controls

There is no prior study of phoneme awareness which is directly analogous to our experimental task. However, given the developmental pattern of PA (see Chapter 5) awareness of phonemes is predicted to be significantly lower in the CI group compared to both of the hearing comparison groups.

The performance data, showing the percentage correct, from the three experimental tasks are provided in table 6.7.

table 6.7 Performance Levels – CI & Hearing Controls

Group		Syllable		Rhyme		Phoneme	
CI	n=19	70.89	(27.54)	56.05	(26.41)	48.63	(20.34)
RL	n=19	64.58	(25.40)	88.42	(18.87)	87.37	(10.87)
CA	n=19	80.32	(22.98)	96.11	(6.15)	88.63	(15.93)

standard deviations are in brackets

Test for differences between groups

Syllable task

The means in table 6.7 show that the CI group had better awareness of syllables than their RL matched controls. An independent t-test was computed to test the significance of the difference between the CI group and their chronological age matched controls. The results showed that the difference in performance was not significant ($t = -1.145$).

Rhyme Task

The CI group had significantly lower performance on the rhyme test when compared to the RL controls ($t = -4.240$, $p<.001$) and when compared to the CA controls ($t = -6.217$, $p<.001$).

Phoneme Task

The CI group had significantly lower performance on the phoneme test when compared to the RL controls ($t = -7.319$, $p<.001$) and when compared to the CA controls ($t = -6.748$, $p<.001$).

Summary

The results show that the CI group had equivalent performance on awareness of syllables to hearing children of the same age and hearing children at the same reading age. Awareness of rhymes and phonemes was significantly lower in the CI group compared to hearing children of the same chronological age and reading age.

Test for Differences in Reaction Times

If the results from the performance levels show that syllable awareness is equivalent in the CI and hearing controls, then the response times for correct judgements should reflect this. The RT of the CI group should be equivalent to the CA controls and faster than the younger, RL controls. The mean response times for correct judgements on the syllable test are given below;

Group		Syllable	
CI	n=19	5500	(3800)
RL	n=19	8300	(4800)
CA	n=19	4000	(3500)

standard deviations are in brackets

The hearing CA group had the fastest RT for correct judgements and the CI group was faster than the reading level matched controls. Independent t tests were computed, comparing the RTs between the CI and RL group and between the CI and CA group. The results showed that there was no significant difference between the CI and their CA controls in response times to correct syllable judgements ($t = 1.108$). The CI group were significantly faster than the RL controls, ($t = -2.045$, $p<.05$).

Summary

The CI group had equivalent reaction times to hearing children of the same age on the syllable test. They were significantly faster on correct syllable judgements than younger children at the same reading level.

6.4 DISCUSSION

Does cochlear implantation benefit phonological awareness?

The aim of this chapter was to investigate the benefit of cochlear implantation on the phonological awareness skills of deaf children. Comparisons were made with less profoundly deaf children with hearing aids and severely deaf children with hearing aids. A benefit of cochlear implant was inferred if the CI group had equivalent performance levels to the group of less profoundly deaf children making good use of residual hearing with hearing aids. A strong benefit of cochlear implant was inferred if the CI group had equivalent performance to severely deaf children. The CI group's performance, on all three experimental tasks, was equivalent to the less profoundly deaf children with hearing aids. On the syllable task, the CI group performed at the same level as the participants who were severely deaf. The comparisons with hearing children showed that awareness of the syllabic constituents of words was at the same level in the CI group as children of the same age and children at the same reading level. Awareness of internal constituents of words, (rimes and phonemes) was significantly delayed compared to age matched and reading level matched controls. Together, these findings show that the fitting of a cochlear implant strongly enhances syllable awareness. Awareness of the internal constituents of syllables remains significantly delayed compared to hearing children of the same age and younger hearing children at the same reading level.

A cochlear implant provides information about high frequency sounds (e.g. consonant phonemes) which would not typically be available to a very profoundly deaf child using conventional acoustical hearing aids (see Chapter 1 for discussion). It is in the high frequencies that acoustic cues to the perception of consonant phonemes are present. If the predictions about the benefit of CI on PA had been based solely on an audiological perspective (where enhanced speech perception was thought to be the sole determinant of PA), then the most obvious enhancement of CI would be predicted at the phoneme level. Perception of high frequencies is the most salient audiological advantage of cochlear implants over conventional hearing aids. However, the comparisons with the deaf and hearing children shows that the strongest benefit of CI on PA was at the level of the syllable. It was found that rhyme and phoneme awareness developed over time in the CI group (see Chapter 5). So, whilst the comparison with deaf and hearing children shows no strong benefit of CI on phoneme awareness, the longitudinal data suggests that awareness of the internal constituents of words is foundational on syllabic awareness. Therefore, as long as development of phonological awareness does occur over time in deaf children with cochlear implants, and this data suggests that it does, the benefit of CI on syllable awareness is an important one because it provides the foundation for intra-syllabic awareness.

Comparison Groups

The questions raised here is whether the fitting of a cochlear implant benefits phonological awareness. This question has been approached by comparing the CI users with deaf children using hearing aids and hearing children. There are many reasons why a comparison between CI users and profoundly deaf hearing aid users may not adequately address the question. Rehabilitation is likely to be an important determinant of outcome for deaf children so, ideally groups of deaf children should be matched for quality and quantity of rehabilitation. An attempt was made to control for this by recruiting hearing aid users from the same schools as the CI children. Partial success was achieved in this, eight of the profoundly deaf children were in the same schools as the CI users. However, even if the rehabilitative approach was equivalent, the CI users have benefited from lengthy assessments and regular reviews by specialist clinicians at implant centres, the deaf children with hearing aids have not. Therefore, the inference of a benefit of cochlear implantation on phonological awareness cannot be attributed solely to the enhanced access to speech frequencies that the implant provides.

We wanted to compare the CI users to profoundly deaf hearing aid users who make good use of residual hearing with hearing aids. The hearing aid users in this study had lower thresholds for pure tones than the CI users, indicating more residual hearing in the PHA group. However, the PHA group in this study do not have enough residual hearing to fall into the 'gold' benchmark category. We relied on teachers identifying children who were making good use of residual hearing with conventional hearing aids, but there is no objective measure with which to confirm teachers' assessments. Equivalent performance on the PA tasks in the profoundly deaf hearing aid users and cochlear implant users was found. If a purely audiological perspective is taken the cochlear implant has had the effect of enhancing the auditory capacity by 7 dB (i.e. the difference between the CI and PHA groups' pure tone unaided thresholds). Compared to the enhancement due to cochlear implantation reported in speech perception studies, which is up to about 20 dB, the enhancement in phonological awareness is relatively small. On the syllable task, the CI users had equivalent performance to the severely deaf children. This represents a 45 dB gain for the CI group (i.e. the difference between the CI and SHA groups' pure tone unaided thresholds). This is a much more significant enhancement. However, the difference between the severe hearing aid group and the profoundly deaf hearing aid users on the syllable task was not significant. In contrast, on the rhyme task, the difference between the severely deaf hearing aid users and profoundly deaf hearing aid users was significant. This suggests that awareness of syllables is less reliant on auditory perception than awareness of internal constituents of words. This finding is entirely consistent with Boothroyd's classification of auditory capacity (see Chapter 1). He suggests that resolution of the rhythm and intonation of speech (detecting syllables falls under this umbrella) is available even in the presence of profound hearing impairment (i.e. with an average pure tone threshold of 110 db HL).

Receptive Vocabulary Acquisition

The hypothesis presented in this thesis is that receptive vocabulary development will support the development of a phonologically structured lexicon which, in turn, supports phonological awareness. The three groups of deaf children were well matched on reading level, but the severely deaf group had the highest receptive vocabulary age of the three groups although the difference was not significant. Therefore, superior rhyme and phoneme awareness in the SHA group may be a product of phonological lexical restructuring due to greater volume of vocabulary acquisition.

If phonological awareness is related to the development of the phonological lexicon, then an ideal additional comparison group would be matched on vocabulary age. The CI group's receptive vocabulary level was significantly lower than that of the reading level comparison group. The receptive vocabulary age of the CI group was 4 years, however, the range extended down to an age equivalent of 2 years. Unfortunately, it was not possible to recruit hearing children, with the same range of receptive language age, who would have the cognitive skills required to complete the experimental tasks.

The Reading Level Matched Design

The comparison with hearing reading level matched participants showed that the deaf children with implants had weaker awareness of intra-syllabic units than younger hearing children who had equivalent word decoding skill. The conclusion is therefore, that the children with implants use different strategies for decoding written words than hearing children, the obvious assumption is that they rely more heavily on visual processing to recognise words. In the next chapter, the role of orthographic knowledge in supporting phonological awareness is explored.

Chapter 7 – Orthographic Effects on Phonological Judgements

7.1 INTRODUCTION

The results presented in Chapters 5 and 6 show that deaf children with cochlear implants and with hearing aids can show awareness of phonological units. The aim of this chapter is to assess the degree to which their phonological awareness reflects true phonological judgements, rather than their ability to recruit orthographic knowledge to aid phonological judgements.

Studies of PA with deaf children and adults have shown that deaf participants rely on orthographic knowledge to a far greater extent than their hearing counterparts. However, some studies have shown that hearing children also find it more difficult to make phonological judgements when orthographic knowledge is not congruent with phonology (see Chapter 2). There is evidence to show that this is the case at the syllable and the rhyme level. Sterne and Goswami (2000) showed that deaf children and their hearing controls found it harder to make judgements about syllable length when words had the same number of letters (i.e. judging that 'hair' and 'baby' have a different number of syllables when the number of letters is the same) than when the number of letters in the word pairs supported the phonological judgement (i.e. 'butterfly' and 'fork', where the number of syllables is different, or 'leaf' and 'bone' where the number of syllables is the same). Campbell and Wright (1988) showed that deaf and hearing children found it easier to make correct rhyme judgements for pairs of written words when the spelling of the rime unit was congruent with the phonological judgement, (i.e. saying that 'box' and 'fox' rhyme), compared to a word pair where the orthography did not support the rhyme judgement (i.e.

'hair' and 'bear'). We have seen from the research reviewed in Chapter 1 that hearing children's phoneme awareness is reciprocally related to literacy instruction.

Controlling for orthographic knowledge is critical when assessing deaf children's phonological awareness. However, it has been seen from the review in Chapter 2, that designing word lists where orthography and phonology are **independently** manipulated is not always possible, orthographically incongruent trials often require a greater degree of phonological sensitivity. In the new experiments the orthographic congruency of trials was manipulated. This enabled the investigation of the difference between trials where spelling knowledge would aid phonological judgements (orthographically congruent) and trials where spelling knowledge would not aid phonological judgements (orthographically incongruent). Finding a marked disparity between orthographically congruent, (high performance) and incongruent trials (low performance) would imply that success on congruent trials was due to the recruitment of spelling knowledge rather than to phonological awareness per se. If an orthographic strategy is the only strategy used to make judgements on PA tasks by deaf children, then performance on the congruent trials should be high, but performance on incongruent trials should be equivalent to chance.

The hypothesis of this thesis is that true phonological awareness can develop in deaf children even though their phonological representations (on which phonological judgements are based) may be different to those of their hearing counterparts. We have seen that phonological awareness in deaf children with cochlear implants is related to the linguistic level of the unit under investigation (Chapter 5). The degree of disparity between orthographically congruent and incongruent trials is predicted to vary, therefore, with the linguistic level of syllable, rhyme and phoneme.

Research Questions

1. To what extent does deaf children's emergent phonological awareness depend on orthographic knowledge?

It is predicted that all deaf participants will find it easier to make phonological judgements when orthographic knowledge can be recruited to aid performance. However, deaf children's phonological judgements on orthographic incongruent trials is expected to vary with the linguistic unit under investigation. If syllable awareness precedes rhyme awareness and rhyme awareness precedes phoneme awareness then we predict that the recruitment of orthography to aid phonological judgements will increase as the linguistic level becomes harder. Therefore, there might be less disparity between congruent and incongruent trials on the syllable task compared to the rhyme task, which in turn might have less disparity between trial types than the phoneme task.

2. Does CI reduce orthographic recruitment in PA tasks for deaf children?

If CI benefits the development of true phonological sensitivity in deaf children, then performance on the orthographically incongruent trials in the CI group should be at least equivalent to the group of profoundly deaf children. If CI strongly benefits the development of true phonological sensitivity in deaf children, then the CI group's performance on the incongruent trials should be equivalent to the group of severely deaf children.

3. Was the improvement in PA over time in the CI group due to increased phonological sensitivity or increased orthographic knowledge?

Overall performance levels on the PA tasks improved between T1 and T2 (Chapter 5). If this improvement was due to increased phonological sensitivity then this will be reflected in improved performance on the orthographically incongruent trials over time. If, however, this improvement was due to increased orthographic knowledge, then improvements over time will only be seen on orthographically congruent trials.

4. **Does early CI reduce orthographic effects in PA tasks more than late fitting?**

If early CI benefits PA, then the participants fitted early will have better performance on orthographically incongruent trials than participants fitted late.

7.2 METHOD

7.2.i Participants

The data from the same groups of deaf and hearing children presented in Chapter 6 are analysed in this chapter.

CI	deaf participants with cochlear implants	n=19
PHA	profoundly deaf participants with hearing aids	n=11
SHA	severely deaf participants with hearing aids	n=10
RL	reading level matched controls (to the CI group)	n=19
CA	chronological age matched controls (to the CI group)	n=19

7.2.ii Experimental Measures

The phonological awareness data presented in Chapter 6 did not distinguish between performance on orthographically congruent versus orthographically incongruent trials, however orthographic congruency was manipulated across each of the experimental tasks. In the syllable task, for the incongruent trials, the number of letters in the cue, target and both distracters was the same; (eg. cue = bird, target = shop, distracter = yoyo, distracter = body). If an orthographic strategy was relied upon, (ie. choosing the item that was the same visual length as the target), performance on incongruent trials would be at chance since all the items have the same number of letters as the cue. The rhyme and phoneme tasks were similar to each other in the way that orthographic congruency was manipulated. The spelling of the unit under investigation (rime unit or initial phoneme) was either the same in both the cue and the target (orthographically congruent trials e.g. 'tree/knee' and 'farm/fat'), or different (incongruent trials e.g. 'fruit/boot' and 'comb/key').

7.3 RESULTS

The results are presented in 3 sections. In the first section research questions 1 and 2 are presented together by linguistic level. In the second section the third research question is presented. The final results section concerns the fourth research question.

7.3.i Orthographic Effect

To what extent does deaf children's emergent PA depend on orthographic knowledge?

It is predicted that all deaf participants will find orthographically congruent (0+) trials easier than orthographically incongruent (0- trials). It is predicted that the effect of orthography will not be equal across experimental tasks, but that the disparity between congruent and incongruent trials will vary with linguistic level. The developmental hypothesis predicts that the disparity will be least for the syllable task, followed by the rhyme task and most marked on the phoneme task.

Does CI reduce orthographic effects in PA tasks for deaf children?

If CI benefits PA then performance on the 0- trials (reflecting true PA) in the CI group should be at least equivalent to the PHA group.

The results relating to both these research questions are presented by linguistic level starting with the syllable task then the rhyme task and finally the phoneme task.

7.3.ii Syllable Test

The results from each group on the congruent (0+) and incongruent trials (0-) are in table 7.1. and plotted in figure 7.1.

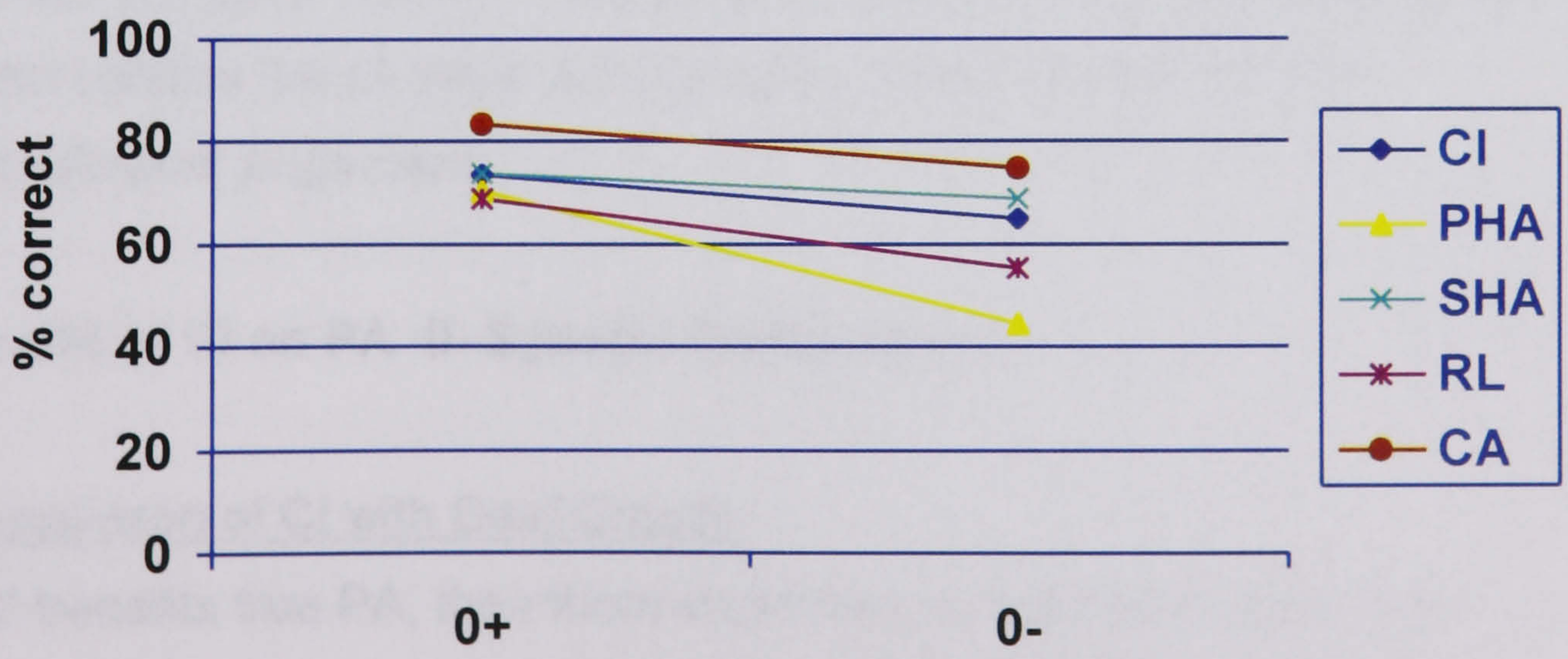
table 7.1 Syllable Test 0+ and 0- Trials

Group	0+		0-	
CI	73.6*	(27.5)	64.9*	(31.2)
PHA	70.1*	(23.6)	44.4	(33.5)
SHA	73.7*	(32.3)	68.9*	(24.6)
RL	68.9*	(28.5)	55.4	(17.2)
CA	83.3*	(24.9)	74.9*	(24.4)

standard deviations in brackets

*group mean significantly different to chance (1-tailed)

figure 7.1 - Orthographic Effect - Syllable Task



Performance on 0- trials Compared to Chance

The data in table 7.1 shows that the CI, SHA and CA groups are above chance on the 0- trials. The PHA and RL groups are not.

Orthographic Effect

Figure 7.1 shows that all groups found the 0- trials harder than the 0+ trials, but the PHA group had greater disparity between 0+ and 0- trials than the other groups. In order to test the significance of the observed orthographic effect Wilcoxon tests were computed for each group. The results are in table 7.2.

table 7.2 Wilcoxon Tests – Syllable Trials

Group	z	p (1-tailed)
CI	-2.137	.05
PHA	-2.674	.01
SHA	-.631	.264
RL	-2.276	.05
CA	-1.803	.05

The results show that there was a significant effect of orthographic congruency for all groups except the SHA group. Most groups, including the two groups of hearing children found it easier to make judgements about syllable length when orthography was congruent with the phonological judgement.

Benefit of CI on PA 0- Syllable Performance

Comparison of CI with Deaf Groups

If CI benefits true PA, then there should be no significant difference between the CI group and PHA groups on the 0- trials. If CI strongly benefits true PA then there should also be no significant difference between the CI group and SHA group. The data in table 7.1 shows that the CI group had better performance on the 0- trials than the PHA group and equivalent performance to the SHA group. In order to test the differences Mann Whitney U tests were computed. The results showed that there was no significant difference in performance on 0- syllable trials between the CI and PHA group (U 67, z –1.627), or between the CI and SHA group (U 90, z -.232). The data in table 7.1 shows that performance on the 0- trials was above chance for the CI and SHA groups, but not for the PHA group. This suggests that the CI group was **not** solely relying on visual orthographic knowledge to make syllable judgements.

Comparison of CI with Hearing Groups

We found that overall performance levels on the syllable task in the CI group was equivalent to the CA group (Chapter 6). If syllable awareness is age appropriate in the CI group and if overall performance on the syllable test was not heavily inflated by the use of an orthographic strategy then the CI participants should have equivalent performance on the 0- trials to the RL and CA controls. The means in table 7.1 show that the CI group had better performance on the 0- trials than the RL controls, although an independent t test showed that this difference was not significant (t = 1.00). An independent t-test was computed to test the significance of the difference between the CI group and their CA controls. The result showed that the difference was not significant (t = –1.096).

Summary

Orthographically incongruent trials were significantly harder than congruent trials for both groups of profoundly deaf children (CI and PHA) and for the hearing children. The CI group was above chance on the 0- trials the PHA group was not although there was no significant difference on performance levels. There was no significant difference between the CI group and SHA group in performance on the 0- trials, but SHA group was above chance on the 0- trials and their performance was not affected by the orthographic congruency of trials. The CI group had advanced performance on the 0- trials compared to their RL controls and no significant difference in performance compared to their CA controls.

These findings suggest that deaf participants with cochlear implants have true phonological awareness of syllables that is age appropriate.

7.3.iii Rhyme Test

The results from each group on the congruent (0+) and incongruent trials (0-), are in table 7.3 and plotted in figure 7.2.

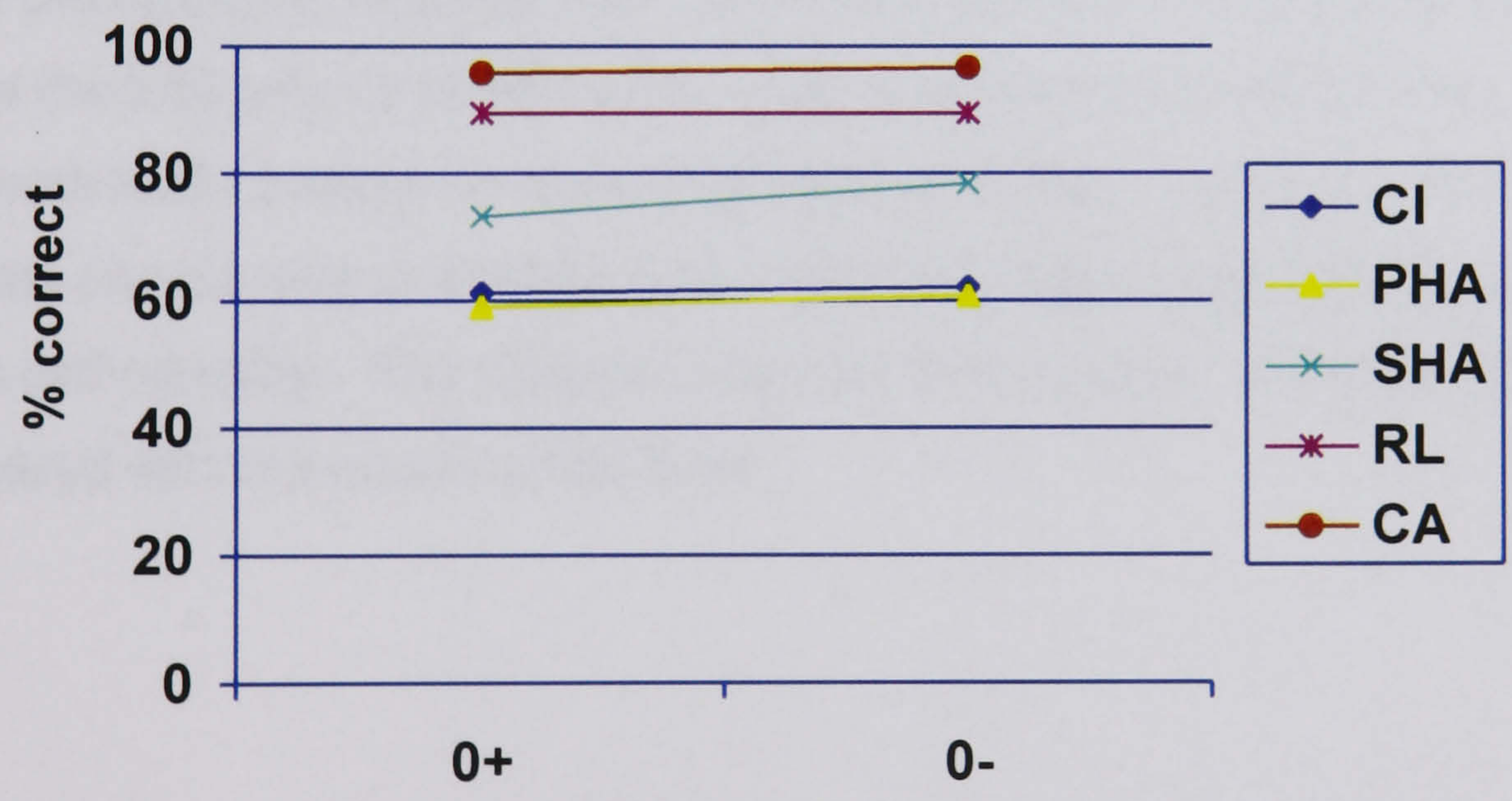
table 7.3 Rhyme Test, 0+ Trials and 0- Trials

Group	0+		0-	
CI	55.2	(29.5)	56.7*	(26.9)
PHA	58.7*	(32.3)	60.6*	(22.4)
SHA	73.1*	(29.6)	78.3*	(27.6)
RL	89.5*	(16.9)	89.4*	(18.5)
CA	95.6*	(8.5)	96.6*	(5)

*group mean significantly different to chance (1-tailed)

standard deviations in brackets

figure 7.2 - Orthographic Effect - Rhyme Task



Performance on 0- trials Compared to Chance

The data in table 7.3 shows that all groups had performance on the 0- rhyme trials that was significantly above chance (1-tailed).

Orthographic Effect

The graph in figure 7.2 shows that none of the groups found the 0- trials harder than the 0+ trials. In the rhyme task, the incongruent trials do not share the rime spelling, but there was still some overlap in graphemes, (i.e. 'light/kite'). Therefore, spelling knowledge may still aid judgements even on incongruent trials. This could account for the fact that no orthographic effect was found on the rhyme test. In order to test this an analysis based on a small set of trials was carried out.

Selective Trial Analysis

Given the degree of orthographic overlap between targets and cues in the 0- rhyme trials a comparison between 0+ trials and 0- trials was carried out using a selection of 3 theoretically hardest 0- trials and 3 theoretically easiest 0+ trials. A subset of trials from the 0- trials was identified. These were trials where the cue and target shared only one grapheme and where one or both of the distracters also shared a grapheme with the cue. A subset of theoretically easiest 0+ trials was identified. These were trials where only one of the distracters shared a grapheme with the cue and where the shared grapheme was **not the initial grapheme**. If an orthographic strategy was used there should be a disparity between the theoretically most difficult 0- trials (low performance) and the theoretically easiest 0+ trials (high performance). Comparison of these trials should reveal whether deaf children's rhyme judgements are reliant on orthography. The selected trials are listed below the grapheme shared with the cue is underlined.

Most Difficult 0- Trials

Cue	**Target**	**Dist.**	**Dist.**
one	run	bike	two
shoe	blue	gold	feet
draw	floor	bath	pen

Most Easy 0+ Trials

Cue	**Target**	**Dist.**	**Dist.**
leg	peg	nail	arm
hand	sand	salt	glove
sock	clock	doll	hat

The percentages correct for these trials are given by group below;

	Hardest 0- Trials %	Easiest 0+ Trials %
CI	53	58
PHA	73	46
SHA	77	73
RL	90	87
CA	93	93

The mean percentages correct show that there was no disparity between the hardest 0- trials (low performance) and the easiest 0+ trials (high performance) for any of the groups.

Benefit of CI on PA - 0- Rhyme Performance

Comparison of CI with Deaf Groups

If CI benefits true PA, then there should be no significant difference between the CI group and PHA group. If CI strongly benefits true rhyme awareness then there should also be no significant difference between the CI group and SHA group. The data in table 7.3 shows that the CI group had worse performance on the 0- trials compared to both the PHA and SHA groups. In order to test the significance of these differences Mann Whitney U tests were computed. The results showed that the difference between the CI and PHA was not significant (U 98, z –.281). The difference between the CI and SHA group was significant (U 48.5, z - 2.148; p <.05).

<u>Comparison of CI with Hearing Groups</u>

We found that the CI group had very delayed rhyme awareness compared to the RL and CA controls (Chapter 6). The means in table 7.3 show a large difference on 0- trials between the CI and their hearing comparison groups. Independent t-tests were computed to test the significance of the differences between the CI group and the RL and CA groups. The results showed a highly significant difference in performance on the 0- trials between the CI group and the RL group (t –4.375; p <.001) and the CA group (t –6.361; p <.001).

Summary

There was no significant orthographic effect on the rhyme task. This was true for all groups of deaf participants and for the hearing participants. Analysis based on a more stringent selection of orthographically hardest trials and easiest trials also confirmed this finding. The fact that no orthographic effect was found on the rhyme task suggests that all groups completed this task based on phonological rather than orthographic knowledge. The CI group was significantly worse on the 0- trials compared to the SHA group and the two groups of hearing controls, but equivalent to the PHA group.

7.3.iv Phoneme Test

The results from each group on the congruent (0+) and incongruent trials (0-), are in table 7.4 and plotted in figure 7.3.

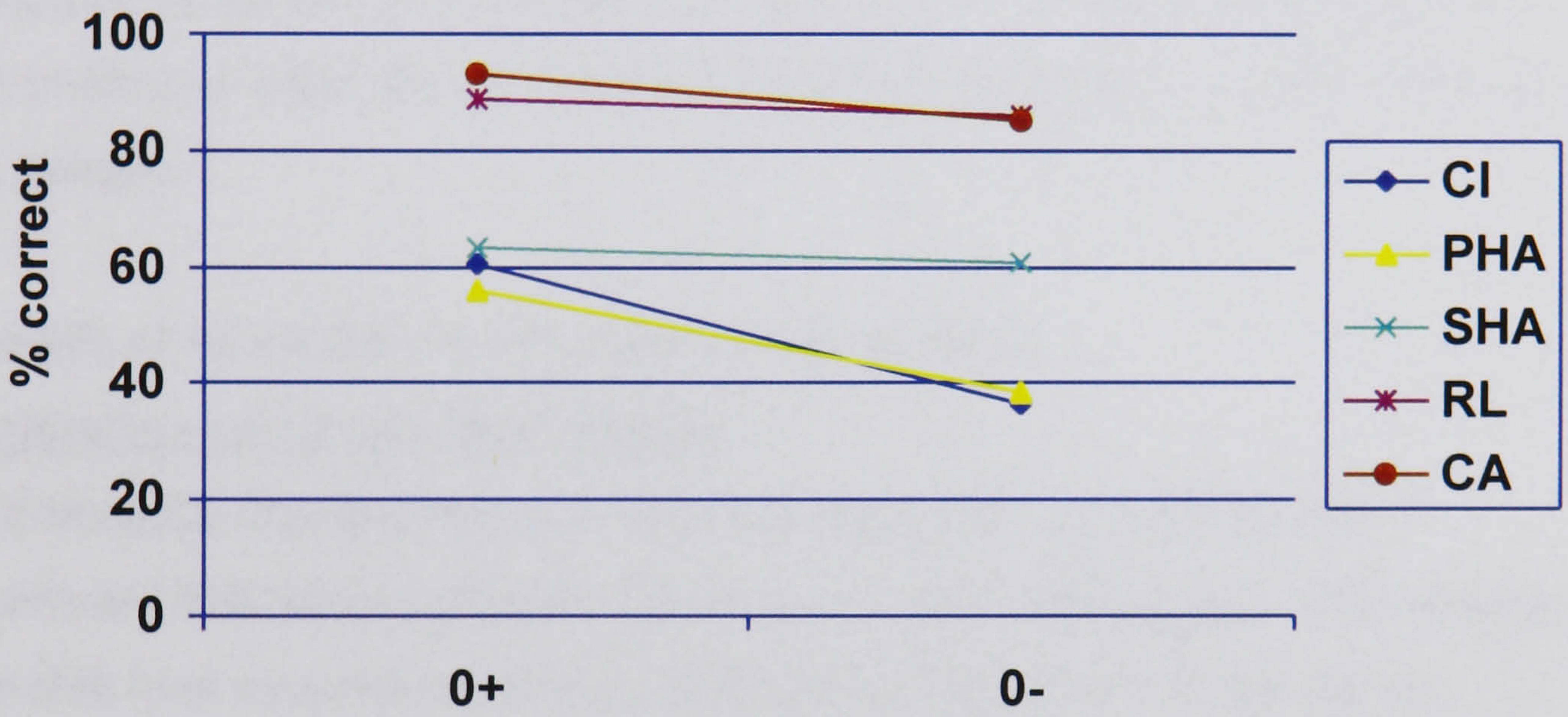
table 7.4 Phoneme Test, 0+ Trials and 0- Trials

Group	0+		0-	
CI	60.6*	(24.5)	36.4	(20.2)
PHA	55.8*	(28.8)	38.4	(20.9)
SHA	63.4*	(18.9)	60.8*	(21.9)
RL	88.8*	(14.2)	86.1*	(12.4)
CA	93.1*	(10.7)	85*	(17.7)

*significantly above chance (1-tailed)

standard deviations in brackets

figure 7.3 - Orthographic Effect - Phoneme Task



Performance on 0- trials Compared to Chance

The data in table 7.4 shows that the CI and PHA groups were not above chance performance on the 0- trials, but the SHA, RL and CA groups were.

Orthographic Effect

The data in table 7.4 shows that all groups found the 0- trials harder than the 0+ trials. The data plotted in figure 7.3 shows that the CI and PHA groups both had large disparity between trial types, but the two hearing groups and the SHA group showed less disparity. In order to test the significance of the observed orthographic effect Wilcoxon tests were computed for each group. The results are in table 7.5

table 7.5 Wilcoxon Tests – Phoneme Trials

Group	z	p (1-tailed)
CI	-3.46	<.001
PHA	-2.06	<.05
SHA	-1.13	.128
RL	-1.14	.126
CA	-2.25	<.05

The results show that there was a significant effect of orthographic congruency for the CI, PHA and CA groups. The orthographic status of the phoneme trials did not significantly affect performance in the SHA and RL groups.

Benefit of CI on PA - 0- Phoneme Performance

Comparison of CI with Deaf Groups

If CI benefits true phoneme awareness then there should be no significant difference between the CI group and PHA group. If CI strongly benefits true awareness of phonemes then there should also be no significant difference between the CI group and SHA group. The data in table 7.4 shows that the CI group had equivalent performance on the 0-trials to the PHA group and lower performance than the SHA group. In order to test the differences Mann Whitney U tests were performed. The results showed that there was no significant difference in performance on 0- phoneme trials between the CI and PHA group (U 104, z –.022), but the difference between the CI and SHA group was significant (U 35, z – 2.191; p<.05).

Comparison of CI with Hearing Groups

In Chapter 6 it was shown that phoneme awareness in the CI group was significantly delayed compared to the hearing comparison groups. The means in table 7.4 show that there was a large difference on the 0- trials between the CI group and the RL and CA groups. Independent t tests showed that these differences were highly significant, (CI and RL controls, t –9.135; $p < .001$) (CI and CA controls, t –7.889; $p<.001$).

Summary

A highly significant effect of orthography was found on the phoneme test for both groups of profoundly deaf children (CI and PHA). The comparison of performance against chance showed that only the severely deaf children were able to make true phoneme judgements. Performance on the 0+ phoneme trials was above chance in the CI and PHA groups. This suggests that the CI and PHA groups were heavily reliant on orthographic knowledge to make phoneme judgements, but the SHA group were able to make correct judgements without recruiting orthographic knowledge. Both groups of hearing children were able to make true phoneme judgements, but the older CA group showed an orthographic congruency effect (0+ trials easier than 0- trials). The younger RL group did not show this pattern. This may be due to enhanced orthographic knowledge in the CA group lead to ceiling performance on the 0+ trials.

7.3.v Development in Phonological Sensitivity over Time in the CI Group

We found that the phonological awareness of the CI group improved over time (see Chapter 5). If this improvement was due to developing phonological sensitivity then we should expect to find increased awareness on 0- trials at T2. However, if the improvement was due to developing orthographic knowledge (which was used to aid phonological judgements) then there would be no improvement on the 0- trials over time.

7.3.vi Development in 0- Trials Over Time

The mean percentages correct for the 0- trials on the syllable, rhyme and phoneme tests from the 18 children who participated in testing at T1 and T2 are given below.

	T1	T2
Syllable 0- Trials	67.9	72.3
Rhyme 0- Trials	58.9	74.5
Phoneme 0- Trials	37.6	47.7

In order to test the significance in improvement over time on the 0- trials the Wilcoxon test for repeated measures was computed. The results showed that there was no significant improvement on 0- syllable trials between T1 and T2 ($z = -.809$). The difference on the 0- rhyme trials over time was significant ($z = -2.576$; $p = <.01$, 2 tailed). The difference between 0- phoneme trials at T1 and T2 was significant at the 1 tailed level ($z = -1.770$; $p <.05$).

Summary

These results suggest that the development of PA over time in the CI group was due to increased phonological sensitivity rather than increased orthographic knowledge. Of interest though is the fact that 0- phoneme performance improved significantly over time, but overall performance on the phoneme test was not found to improve significantly over time (see Chapter 5). This suggests that real phonological sensitivity of phonemes occurred over time. In order to explore this further we need to compare development of 0- trials with the 0+ trials.

7.3.vii Development in 0+ Trials Over Time

The mean percentages correct for the 0+ trials on the syllable, rhyme and phoneme tests from the 18 children who participated in testing at T1 and T2 are given below.

	T1	T2
Syllable 0+ Trials	75.8	79.8
Rhyme 0+ Trials	57.8	78.3
Phoneme 0+ Trials	61.2	64.9

In order to test the significance in improvement over time on the 0+ trials the Wilcoxon test for repeated measures was computed. The results showed that there was no significant improvement on 0+ syllable trials between T1 and T2 ($z = -.707$). The difference on the 0+ rhyme trials over time was highly significant ($z = -3.297$; $p = <.001$, 2 tailed). The difference between 0+ phoneme trials at T1 and T2 was not significant ($z = -.332$).

Summary

The improvement in 0+ syllable trials over time was of a similar magnitude to that of the 0- trials. The improvement on 0+ rhyme trials over time was highly significant and of a slightly higher magnitude to improvement in 0- rhyme trials over time. Improvement on 0+ phoneme trials over time was not significant. These findings suggest that, contrary to the conclusion reached in Chapter 5, the CI group did make significant improvement in phoneme awareness over time and this was entirely due to **true phonological sensitivity** rather than the recruitment of orthographic knowledge to aid phoneme judgements. Conclusions about phoneme awareness in CI children must be tempered by the fact that overall performance of 0- phoneme trials at T2 was not significantly different to chance.

7.3.viii Does early CI reduce orthographic effect on PA tasks more than late fitting?

There were no significant differences in overall performance at T1 or at T2 on the experimental tests between the participants fitted early with their implants and participants fitted late (Chapter 5). If the experimental hypothesis is correct (that early implant fitting benefits PA) the two groups should differ on the degree to which orthographic knowledge is recruited to aid phonological judgements. The prediction is that the CIE group should show better performance on the 0- trials compared to the CIL group. The word reading levels of the two groups was equivalent at T1, so any differences found between the groups cannot be attributed to a difference in reading age.

Difference between CIE and CIL Groups at T1 on 0+ and 0- Trials

The means for the 0+ and 0- trials on all the experimental measures at T1 are presented in table 7.6.

table 7.6 CIE & CIL 0+ and 0- trials – All Linguistic Levels T1

	Syllable		Rhyme		Phoneme	
	0+	0-	0+	0-	0+	0-
CIE	69.1*	61.7*	61.1*	62.1*	57.2*	38
CIL	77.6*	67.9*	49.9	51.8	63.6*	34.9

*different to chance (1-tailed)

Performance on 0- trials Different to Chance

The data in table 7.6 shows that both groups had above chance performance on the 0- syllable trials, but only the CIE group had above chance performance on the 0- rhyme trials at T1. Whilst both CI groups were able to make judgements above chance level on 0+ phoneme trials, neither group was above chance on the 0- phoneme trials at T1.

Test for Group Differences on 0- Trials at T1

In order to test the possible significance of the difference between the groups on the 0- trials, Mann Whitney U tests were computed. The results showed that there were no significant differences between the groups at the syllable level ($U = 30$, $z = -.160$) or the rhyme level ($U = 35$, $z = -.820$) or the phoneme level ($U = 28.5$, $z = -.322$).

Individual Data

It is possible that wide variability within groups masked real differences between the two groups on the 0- trials. Therefore, the actual percentage of participants above chance performance was considered. The percentage of participants above chance performance in each group is given below;

	0- Syllable	0- Rhyme	0- Phoneme
CIE	56%	44%	0%
CIL	60%	40%	10%

The percentage of participants above chance on the 0- trials at T1 supports the null finding of a difference between the two groups. In Chapter 4 it was shown that 3 participants *'mm' 'dj' and 'cl',* in the CIL group, were above chance on the phoneme test, but not on the rhyme test. It was suggested that their phoneme awareness would be strongly reliant on orthographic knowledge. Analysis of their individual scores showed that this conclusion was correct for two of the participants ('*mm*' and '*cl*'). Their performance on the 0- phoneme trials was not above chance. However, *'dj'* was the one subject in the CIL group who showed above chance performance on the 0- Phoneme trials at T1. She had a raw score of 58%. This result contradicts the developmental hypothesis, since it suggests that phoneme awareness can develop in the absence of intra-syllabic awareness.

Summary

The results show that the two groups had similar performance levels on the 0- trials at T1. However, the CIE group's performance on the 0-rhyme trials was significantly different to chance. Both groups showed the greatest orthographic effect on the phoneme test. Neither group's performance was significantly different to chance on the 0- phoneme trials at T1.

Difference between CIE and CIL Groups at T2 on 0+ and 0- Trials

The means for the 0+ and 0- trials on all the experimental measures at T2 are presented in table 7.7.

table 7.7 CIE & CIL 0+ and 0- Trials all Linguistic Levels at T2

	Syllable		Rhyme		Phoneme	
	0+	0-	0+	0-	0+	0-
CIE	71.6*	64.2*	76.8*	84.3*	61*	50.9
CIL	88.1*	80.3*	79.8*	64.7*	68.8*	42

* different to chance (1-tailed)

Performance on 0- trials Compared to Chance

The data in table 7.7 shows that both groups maintained above chance performance on the 0- syllable trials at T2. The CIL group developed 0- rhyme sensitivity that was above chance at T2. Neither group had developed 0- phoneme awareness at T2 that was significantly different to chance, although the actual performance levels on the 0- trials improved overall (see section 7.4).

Test for Group Differences on 0- Trials at T2

In order to test the possible significance of the difference between the groups on the 0- trials, Mann Whitney U tests were computed. The results showed that there were no significant differences between the groups at the Syllable level ($U = 29$, $z = -.987$) or the Phoneme level ($U = 31.5$, $z = -.798$). The difference between 0- Rhyme trials at T2 was significant at the 1-tailed level ($U = 20.5$, $z = -1.822$; p .039).

Individual Performance

The difference between the CIE and CIL groups on 0- rhyme awareness should also be confirmed by examining the actual number of participants within each group who were above chance level on the 0- trials. The percentage of participants above chance on the 0- trials (syllable, rhyme and phoneme) at T2 is given below;

	0- Syllable	0- Rhyme	0- Phoneme
CIE	67%	78%	44%
CIL	78%	44%	22%

A much higher percentage of children in the CIE group were above chance on the 0- rhyme trials compared to the CIL group. This supports the finding of a significant difference between the two groups on 0- rhyme trials. Nearly half of the children in the CIE group were above chance on the 0- phoneme trials at T2, whereas only two participants were above chance on these trials in the CIL group. The two participants in the CIL group above chance on these trials were *'sg'* and *'lp'*. Both these participants had developed a significant amount of spoken language prior to the fitting of a cochlear implant. As discussed previously (see Chapter 5) the fact that these children had developed spoken language using hearing aids means that they are not characteristic of the general CI population. Therefore, if we discount these two children none of the children fitted late with cochlear implants who had not developed spoken language prior to CI fitting developed true phoneme awareness at T2.

The subject *'dj'* who was above chance on the 0- phoneme trials at T1 was not above chance at T2. Her raw score on the 0- phoneme trials at T2 was 50%. This finding suggests that her phoneme awareness was strongly dependent on orthographic knowledge. The individual pattern of performance on the phonological awareness trials for all the children fitted with cochlear implants at T1 and T2, with the tests divided into 0+ and 0- trials is given in Appendix D.

Summary

Whilst performance on the 0+ rhyme trials was essentially equivalent in the two groups at T2 the CIE group had significantly better performance on trials where orthographic knowledge could not be used to aid phonological judgements. Neither group's performance was significantly different to chance on the 0- phoneme trials at T2, but the percentage of participants above chance on these trials was higher in the CIE group.

7.4 DISCUSSION

To what extent does deaf children's emergent phonological awareness depend on orthographic knowledge?

The profoundly deaf children (CI and PHA groups) found it easier to make correct phonological judgements on orthographically congruent trials compared to incongruent trials in the syllable and phoneme tasks. The CI group was able to make correct syllable judgements without relying on orthographic knowledge. The CI and PHA group were able to make correct rhyme judgements without relying on orthographic knowledge. The severely deaf children were able to make phonological judgements about sounds in words that was not dependent on orthographic knowledge at any linguistic level. The CI group's phoneme awareness of congruent trials was above chance, but they were strongly dependent on the recruitment of orthographic knowledge since performance on the 0-trials was significantly worse.

Did the orthographic effect vary with linguistic level in a way that supported the developmental hypothesis of PA?

The developmental hypothesis predicts that the orthographic effect will be related to linguistic level, with easier linguistic levels showing least disparity between congruent and incongruent trials, if task complexity is equated. The results showed that there was an orthographic effect on the syllable task and a highly significant effect on the phoneme task, for both the profoundly deaf and hearing groups. There was no orthographic effect on the rhyme task. The finding of a significant orthographic effect on the syllable test and the absence of one on the rhyme test contradicted the developmental hypothesis's predictions. One explanation could be task construction. It seems likely that the orthographic manipulation on the syllable task (to make all items in the trial have the same number of letters) meant that the incongruent trials required greater phonological sensitivity than the congruent trials. Evidence to support this conclusion is demonstrated by the fact that all the deaf groups performed above chance level on the incongruent trials, which they would not have been able to do if a purely orthographic strategy had been used. However, the fact that the severely deaf children did not have a large disparity in performance between the 0+ and 0- syllable trials somewhat contradicts this explanation. A direct comparison of the orthographic effect is most valid between the Rhyme and phoneme tasks because the orthographic effect was investigated using the same technique (i.e. varying the spelling of the linguistic unit under investigation). The results from a comparison of the orthographic effect between the rhyme and phoneme tests supports the developmental predictions. There was no orthographic effect on the rhyme task, but a highly significant effect on the phoneme task. This was the case for both profoundly deaf and hearing participants.

Overall, the findings suggest that phonological awareness in deaf children is, initially strongly reliant on orthographic knowledge. The ability to make purely phonological judgements seems to be related to the linguistic level, but also to auditory capacity. Participants with more residual hearing, (i.e. severe rather than profound hearing loss) showed greater ability to make phonological judgements without the help of orthographic knowledge.

Does CI reduce orthographic effects in PA tasks for deaf children?

A benefit of cochlear implant would be inferred if performance on the 0- trials was equivalent in the CI group to the PHA group. A strong benefit would be inferred if performance in the CI group was equivalent to the SHA group. Overall, there was very little difference in performance and pattern of disparity between congruent and incongruent trials between the

CI and PHA groups. However, there was quite a large difference, both in performance levels and in the reliance on orthographic knowledge to make phonological judgements between the CI and the severely deaf children. In Chapter 6 it was shown that mean performance levels on the syllable task were equivalent in the three groups of deaf participants. We found here, that the CI group had equivalent performance on the 0-syllable trials to the PHA and SHA groups. These findings support the conclusion reached in the previous chapter, that CI benefits phonological sensitivity to syllables.

Was the improvement in PA over time in the CI group due to increased phonological sensitivity or increased orthographic knowledge?

We found that the improvement in phonological awareness over time in the CI group was not limited to the orthographically congruent trials, but that significant improvement on incongruent trials also took place. This shows that true phonological sensitivity did develop over time in the CI group. Perhaps the most unexpected finding was that the CI group made more improvement orthographically incongruent phoneme trials than congruent trials, although as the CI group's performance was not significantly different to chance on these trials at Time 2. The literature of PA development in hearing children strongly suggests that phoneme awareness develops with literacy instruction. We would expect, therefore that deaf children's phoneme sensitivity would also be strongly related to literacy instruction. The subsequent prediction is that improvement in phoneme awareness would be first evidenced on congruent trials because the grapheme knowledge can support phoneme sensitivity. The CI group were above chance on the congruent phoneme trials at Time 2, but not the incongruent trials. This suggests therefore, that the improvement over time on the 0- phoneme trials is due only to the six children who were above chance performance on the 0- phoneme trials at T2. These children were all above chance on the congruent phoneme trials at T1. Therefore, their true phoneme awareness was initially scaffolded by orthographic knowledge.

Does early CI reduce the orthographic effects in PA tasks more than late fitting?

The results showed that there were no significant differences between the participants fitted early and those fitted late on performance of orthographically incongruent trials at T1. At T2, despite the fact that the two groups had very similar overall performance levels, the early group was significantly better at making judgements about rhymes in the absence of orthographic knowledge. There was an indication that true awareness of phonemes was developing faster in the CIE group. These findings support the hypothesis that early fitting with an implant improves the underlying organisation of the phonological lexicon. However, it is not possible to make any conclusive statements about this since the children in the early group had been using their implants for longer than the children fitted later. Therefore, we cannot be sure that the timing of implant fitting (rather than duration of implant use) is the reason for enhanced phonological sensitivity in the CIE group.

In the next chapter the determinants of phonological awareness in the CI group are explored.

Chapter 8 – The Determinants of Phonological Awareness

8.1 INTRODUCTION

It has been shown that deaf children with cochlear implants can possess phonological awareness at the syllable and rhyme level that is not solely dependent on orthographic knowledge (Chapter 7). In this chapter the determinants of phonological awareness are explored.

In Chapter 1 a case was made for the central role of vocabulary acquisition in the development of grammar (Bates & Goodman, 2001; Locke, 1987). Several prominent theories of phonological development also place vocabulary acquisition at the heart of phonological development (Bybee, 2001; Metsala & Walley, 1998). These theories weight the importance of vocabulary development differently and the role of vocabulary in determining linguistic knowledge varies according to the theoretical interest and perspectives of the authors. Locke (1997) places utterance collection at the centre of his Neurolinguistic Development Theory because it is seen as the trigger for a cognitive mechanism (the analysis and computational mechanism) which is responsible for the identification of recurring patterns in the language. The analysis and computational mechanism is poised to be "turned on" sometime before the 24th month of life. If the volume of stored utterances is low or absent around this sensitive period then the mechanism will not be "fully turned on" and so not optimally tuned to operate. Whilst there is currently little empirical data to support and extend Locke's theoretical position the type of mechanism he describes can account for some behavioural data. The persisting grammatical and literacy impairments seen in children with specific language impairment (despite improvement in surface level performance) may be evidence of weak underlying grammatical representation. This theory can also account for the results of Charlier and Leybaert (2000) that were reported in Chapter 2. They found that deaf children who had early unambiguous phonological input (using cued speech) were able to develop age appropriate rhyme awareness. Older deaf children who had been introduced to cued speech later in childhood continued to have difficulties with the rhyme task despite having unambiguous input through the visual domain. Clarity of input is clearly an important factor in the development of phonological knowledge, but timing also appears to be a critical factor. Other theorists (i.e. Bates & Goodman, 2001) are not explicit about the timing of the vocabulary burst in terms of determining ultimate grammatical knowledge or representation. Their thesis is that grammar and the lexicon are not separable and grammar is not an innate module that determines lexical acquisition. The lexical restructuring hypothesis of Metsala and Walley (1998) also suggests that vocabulary acquisition is responsible for the formation of a fully segmented phonological lexicon. Metsala and Walley make no claim about the importance of the timing or volume of items stored on the resulting structure (i.e. in terms of eventual architecture or size of unit of organisation). If Locke's theory is correct and timing of the vocabulary burst is important then it is predicted that delayed acquisition of language will result in impoverished phonological representation. This will be evidenced by poor awareness of constituent sounds in words as tested using phonological awareness measures.

In this thesis I argue that phonological representation is not solely determined by auditory perception, but that vocabulary acquisition and the timing of vocabulary acquisition is causal in the emergence of a **structured** phonological lexicon. The structure of the phonological lexicon is tested using the tasks of phonological awareness. Whilst the ability to hear or perceive speech is important for the development of phonology and spoken language, the role that vocabulary acquisition is central in determining the degree to which the phonological representations are segmentally organized is tested here. The derivation of phonological structure is considered to be a product of a cognitive mechanism where vocabulary acquisition is the trigger for the restructuring of knowledge acquired through the input. Auditory capacity may be related to phonological awareness because of its role in spoken language acquisition, but the role of vocabulary acquisition in determining the ultimate structure of the representations is the area investigated in this chapter. In the light of Locke's theory, degree of **delay** rather than actual vocabulary knowledge (or level) is the more critical determinant of phonological awareness. To summarise, the two theoretical positions regarding the determinants of PA are;

1. auditory perception is not the sole determinant of PA but vocabulary acquisition triggers a mechanism that acts on the input to derive phonological structure

2. the timing of vocabulary acquisition rather than actual vocabulary level is crucial for PA.

These theoretical positions can be tested in two ways. Firstly, if vocabulary delay rather than vocabulary knowledge determines phonological awareness then delayed phonological awareness would be predicted for deaf children who have large delays in vocabulary acquisition. This in itself would not be sufficient to support the theory. However, if their PA skills were worse than that of another group of deaf children who have equivalent vocabulary age, but relatively less delay then this would provide stronger support for the theory. If auditory perceptual level does not directly determine degree of segmental organisation of the phonological lexicon then this prediction should be upheld regardless of auditory perceptual levels. Another way to test of the hypothesis is by showing that children with delayed vocabulary learning have deficits in phonological awareness tasks regardless of the level of auditory perceptual skill. Therefore, **hearing** children with delayed lexical development should have deficits on the tasks of phonological awareness. Children with specific language impairment (SLI) have delayed vocabulary acquisition despite having no apparent auditory perceptual difficulties. If delayed vocabulary acquisition itself leads to deficits in PA, then a group of children with SLI should have poorer performance on the PA tests compared to a group of hearing children with equivalent vocabulary ages.

One difficulty in testing the hypothesis that vocabulary delay determines phonological awareness in deaf children is that the experimental tasks of phonological awareness rely, to some degree on auditory perceptual skill. Therefore, absolute levels of performance on these tests may reflect auditory capacity more than the representational organisation of the lexicon. In addition to perception it is possible that other factors may contribute to success on the phonological awareness tasks. The tests of phonological awareness were designed so that the cognitive demands were low, however, it is possible that general IQ may contribute to task performance. Similarly, the tasks were designed to ensure that short-term memory demands were minimal. The lexical restructuring theory suggests that the development of a phonologically structured lexicon supports phonological processing, including phonological short-term memory (Metsala, 1999). This account suggests that phonological short-term memory and phonological awareness are both supported by the development of the phonologically structured lexicon. Therefore, phonological short-term memory is not predicted to be **causally** related to phonological awareness. Short-term memory might be related to phonological awareness however, this relationship is expected to mediated by vocabulary knowledge. As has already been discussed in Chapter 1, in hearing children phonological awareness is reciprocally related to reading (at least at the level of the phoneme). Therefore, it is possible that a reciprocal relationship also exists between reading and phonological awareness in deaf children. However, if such a relationship does exist in deaf children it is likely to be initially restricted to transparent grapheme/phoneme relationships. So, reading level might be related to trials where orthographic knowledge could be used to aid phonological judgements, but a causal relationship between reading and true phonological sensitivity is not predicted. In this chapter the determinants of true phonological awareness are investigated. Only those trials which required true phonological sensitivity (i.e. orthographically incongruent trials) are used. The significance and specificity of the relationship between vocabulary (level and delay) and phonological awareness can be explored by investigating the longitudinal relationship between vocabulary at T1 and true phonological awareness (measured by the orthographically incongruent trials) at T2.

<u>Research Questions</u>

1. **What are the determinants of phonological awareness in deaf children with cochlear implants?**

   It is predicted that vocabulary delay (rather than vocabulary level or volume) will be the critical determinant of true phonological awareness in the CI group.

2. **Does delayed acquisition of vocabulary, rather than volume of vocabulary, lead to deficits in phonological awareness?**

   It is predicted that **delayed** vocabulary development will inhibit the development of phonologically structured lexicon, which will be evidenced in weak phonological awareness. This theory will be tested by comparing the PA performance of deaf children with delayed and less delayed vocabulary and by comparing the progress of hearing children with SLI compared to a vocabulary age matched group.

8.2 METHOD

8.2.i Participants

Research Question 1

For research question 1, the CI group is analysed as a whole (CI) in order to yield sufficient participants for correlation analyses.

Group performance on the critical measures to be used are given in table 8.1. Age equivalent (age) and standard scores ('t' or 'std', depending on the test used) from T1 are provided. The speech perception scores are the percentage of words correctly identified at T1 without lip cues (ASP).

table 8.1 Participant Summary - CI Group (n=19)

Matrixes	BPVS		Speech Perception	Digits (STM)	Reading
t	Age	Std	ASP	Age	Age
55.63 (13.98)	4.16 (1.57)	58.58 (16.73)	73.07 (20.07)	5.22 (1.69)	7.08 (1.31)

standard deviations in brackets

The CI group's performance on the orthographically incongruent trials (0-) at T2 are presented below;

0- Syllable	**0- Rhyme**	**0- Phoneme**
72.3 (27.9)	74.5 (26.6)	47.7 (22.1)

standard deviations in brackets

Research Question 2 – Deaf Participants

The second research question is tested using two groups of deaf children **matched for vocabulary level** (using the age equivalent score which is derived from the BPVS raw score), but who differ on degree of vocabulary delay (derived from the standard score which is a measure of the degree of delay relative to the standardised population). These groups are referred to as V+ (relatively less delayed compared to hearing norms) and V- (relatively more delayed compared to hearing norms). It was not possible to draw these groups out of the CI group, so data from all the deaf children tested was used (i.e. profound hearing aid users (PHA) and severe hearing aid users (SHA)). One group has greater delay in vocabulary acquisition (V-) represented by lower standard scores on the BPVS, than the other group (V+) who have relatively higher standard scores. Only six pairs of participants could be matched for vocabulary level who differed in degree of vocabulary delay. Individual pairs are given in 8.2 showing the match on vocabulary age and the difference in the BPVS standard scores. Information on the group membership is also provided.

table 8.2 Advanced and Delayed Vocabulary Acquisition, Matched Groups

V+ Group			V- Group		
BPVS Age	BPVS Std	Group	BPVS Age	BPVS Std	Group
7.42	97	CIE	7.42	72	PHA
5.50	91	SHA	5.75	58	SHA
5.92	82	CIE	5.92	69	CIL
5.83	79	SHA	5.42	59	PHA
4.92	72	CIE	4.92	56	PHA
3.42	60	CIE	3.50	41	CIL

The groups' chronological age, non-verbal reasoning and short-term memory ages are given below. Independent t-tests were run to test the significance of any differences between the groups on these variables. The groups did not differ in non-verbal reasoning or short-term memory. The V+ group were significantly younger than the V- group ($t = -7.52$; $p=<.001$).

	CA	Matrixes	STM Age
V+	7.39 (.53)	62.50 (10.48)	6.98 (1.79)
V-	10.18 (.74)	61.67 (11.64)	6.19 (2.60)

standard deviations in brackets

Research Question 2 – Hearing Participants

In order to address the second research question we also compare a group of children who have specific language impairment (SLI) to a group of hearing children matched for vocabulary age (VAM). The VAM group are drawn from the group of hearing children who were matched for reading level to the CI group (presented in Chapter 6). They have no history of delayed speech and language acquisition or hearing difficulties (sensorineural or conductive hearing loss). None of the VAM participants were, or had been, on the special educational needs register at school. The participant summary is given in table 8.3.

table 8.3 Participant Summary – SLI and VAM Controls

Group	CA	Non-verbal Reasoning	BPVS Age	BPVS Std	STM Age	Reading Age
SLI n=12	8.44	49.25	6.62	88.25	4.95	7.18
	(1.56)	(10.35)	(1.52)	(7.09)	(1.9)	(1.85)
VAM n=9	6.66	49.67	6.66	100.11	5.08	7.00
	(.70)	(8.06)	(1.04)	(10.11)	(1.31)	(1.43)

standard deviations are in brackets

All the SLI participants had a history of language impairment, however, the group's receptive vocabulary standard score at the time of testing was just within normal limits (88.25, where 100 is the mean, std of 15). Developmental history showed that these participants' receptive vocabulary skills had been delayed, but improved with specialised teaching and intensive speech and language therapy. They continued to have significant language impairments requiring the provision of intensive speech and language therapy.

Independent t-tests showed that the groups differed significantly in chronological age ($t = -3.168$, $p<.01$) and on the BPVS standard score (t

= 3.169, $p<.01$). The SLI group are significantly older than the VAM group and they are significantly delayed in vocabulary acquisition (compared to the standardised norms) whereas the VAM group are not delayed. The two groups had equivalent non-verbal reasoning scores and age equivalent scores on the test of short-term phonological memory.

8.2.ii Measures

A significant effect of orthographic congruency was found on the syllable and phoneme tasks at T1 and T2 (Chapter 7). This suggests that deaf children were recruiting orthographic knowledge to make phonological judgements. The theoretical predictions in this chapter are for the orthographically incongruent trials (0-) since performance on these trials represents true phonological sensitivity.

The speech perception measure, receptive vocabulary measure, word reading test and non-verbal reasoning measure used to analyse the determinants of PA in the CI group have already been described in Chapters 4 and 5.

8.3 RESULTS

8.3.i The Determinants of PA in Deaf Children with CIs

It is predicted that **delay** in the acquisition of vocabulary (BPVS standard score) will inhibit the development of a phonologically structured lexicon. Phonological awareness tasks are measures of the degree to which the lexicon is phonologically structured. Therefore, a positive correlation between vocabulary standard score (a higher standard score means less delay) and phonological awareness (0- trials) was predicted. The vocabulary **standard score** is the main variable of interest since it is an indicator of relative delay.

It is predicted that auditory capacity (measured by speech perception (ASP)) will be indirectly related to performance on the phonological awareness measures of 0- trials. The relationship between speech perception and PA is predicted to be mediated by vocabulary learning. We have already shown in Chapter 4 that there was a longitudinal association between speech perception at T1 and the BPVS standard score at T2 in the CI group.

If vocabulary delay is the critical determinant of true phonological awareness then it should be significantly related to performance on the 0-trials at T2 even after the contribution of other possible determinants is controlled. It is predicted that auditory speech perception will be related to PA via the mediating variable of vocabulary delay. It is possible that non-verbal IQ (matrices), short-term memory (STM) and reading age contribute to performance on the PA tasks. Therefore, in order to assess the specificity of the predicted variable (BPVS std score) on PA performance it is first necessary to examine the relationship between all these variables at T1.

8.3.ii Relationships between predictor variables at T1

Pearsons correlational analyses were computed. Correlations between the measures (Matrices, Reading Age, BPVS Age & std, STM Age and ASP) at T1 are presented in table 8.4.

table 8.4 Correlations Predictor Variables T1

	Matrix t-score	Read Age	BPVS Age	BPVS std	STM Age	ASP
Read Age	.446					
BPVS Age	.284	.667**				
BPVS std	.204	.373	.875***			
STM Age	.374	.416*	.674***	.670**		
ASP	.017	.014	.466	.608*	.291	

Associations between Predictor Variables at T1

At T1, audio speech perception was significantly associated with the BPVS standard score and the association with BPVS age was significant at the 1-tailed level. This supports the finding in Chapter 4 of a longitudinal relationship between speech perception and vocabulary acquisition in the CI group. There was no significant relationship between non-verbal reasoning and BPVS or speech perception at T1. There was no relationship between reading age and the BPVS standard score or speech perception at T1. There was a relationship between STM and BPVS standard score at T1, but STM was not related to speech perception. Short-term memory is not predicted to be a significant predictor of PA performance instead we expected that any relationship found between STM and PA will be mediated by vocabulary.

8.3.iii Longitudinal Relationship Between Predictors at T1 and PA at T2

Time-lag Pearsons correlations were computed. The results are in table 8.5.

Incongruent Trials

table 8.5 Time lag correlations

	Matrix t-score	Read Age	BPVS Age	BPVS std	STM Age	ASP	Syllable 0-	Rhyme 0-
Syllable 0-	.380	.333	.474*	.384	.465	.132		
Rhyme 0-	-.038	.103	.590**	.608**	.403	.742**	.396	
Phoneme 0-	.510*	.113	.320	.432	.388	.215	.506*	.269

* significant at .05, ** at .01, *** at .001 (2-tailed)

The CI group were not above chance on the incongruent phoneme trials at T2, therefore, correlations are likely to be unreliable and will not be discussed further.

Vocabulary Standard Score

The vocabulary standard score at T1 was significantly associated with 0- rhyme trials at T2, but not with the 0- syllable trials. At T1, the vocabulary standard score was significantly related to audio speech perception. Therefore, it is possible that the relationship between vocabulary standard score and rhyme awareness might be mediated by speech perception. This is contra to the predictions made. To test this, partial correlations were computed, holding audio speech perception constant. The results showed that the relationship between vocabulary standard score at T1 and rhyme awareness of orthographically incongruent trials at T2 was no longer significant (r. 255). This suggests that the relationship between vocabulary delay and rhyme awareness was mediated by speech perception.

Audio Speech Perception

We predicted that if a relationship existed between audio speech perception and phonological awareness then this would be mediated by vocabulary. Speech perception at T1 was significantly associated with 0- rhyme trials, but not 0- syllable trials at T2. Given the relationship between speech perception and the BPVS standard score at T1 it is possible that the relationship between ASP and the 0- rhyme performance is mediated by vocabulary. In order to test this, a partial correlation controlling for vocabulary standard score was computed. With vocabulary held constant, ASP at T1 remained significantly correlated with 0- rhyme trials at T2 (r. 574; $p<.05$, 2 tailed). This result is not in line with a priori predictions and taken together with the evidence presented in the previous section it seems that ASP was an independent predictor of true rhyme awareness.

Non-verbal Reasoning

Non-verbal reasoning was not significantly associated with performance on the 0- syllable or 0- rhyme trials at T2.

Phonological Short Term Memory

There was no significant correlation between short-term memory at T1 and the 0- trials at T2, however, the relationship with 0- syllable trials was approaching significance. It was predicted that this relationship, if found, would be mediated by vocabulary. Short-term memory age was correlated with vocabulary (age and std score) at T1. A partial correlation was computed with short-term memory and 0- syllable and rhyme trials, holding vocabulary (std score) constant. The results showed that when vocabulary was controlled, the relationship between short-term memory and the syllable trials was no longer significant (r.222) neither was the relationship between short-term memory and the rhyme trials (r.031). This finding suggests that the weak relationship between phonological short-term memory at T1 and phonological awareness at T2 was mediated by vocabulary.

If this is true, then the significant relationship between vocabulary (std score) and rhyme awareness should remain constant when short-term memory is held constant. To test this a partial correlation was computed. The results showed that when short-term memory age was held constant, the relationship between vocabulary standard score at T1 and rhyme awareness at T2 was still significant ($\underline{r}$ .497; $p<.05$, 2 tailed).

Reading Age

Reading age at T1 was not significantly associated with performance on the 0- syllable or 0- rhyme trials at T2.

Summary – Longitudinal Predictors of PA in the CI Group

Degree of delay in vocabulary acquisition at T1 was not a specific predictor of true phonological awareness at T2 at the syllable or rhyme level. Although there was a longitudinal relationship between vocabulary acquisition (BPVS std score) and true rhyme awareness at T2, this relationship was mediated by speech perception. Audio speech perception at T1, emerged as the strongest predictor of true rhyme awareness at T2, but it was not a predictor of true syllable awareness.

This may be due to the relatively low auditory capacity demands required for syllable awareness. Boothroyd states that awareness of rhythm (i.e. syllables) can be achieved in the presence of near total hearing impairment whereas awareness of speech segments (vowels and consonants) is affected by the degree of hearing impairment (see Chapter 1). Another explanation is due to the difference in task demands between the syllable and rhyme tests (see Chapter 5). The weak correlation between the syllable and rhyme task at T2 (r. 396) lends some support for this explanation. Neither non-verbal reasoning nor reading age at T1 was related to PA performance at T2. There was a weak association between phonological short-term memory and 0-syllable awareness, however this was mediated by vocabulary.

8.3.iv Does delayed acquisition of spoken language lead to deficits in phonological awareness?

If delayed vocabulary acquisition, rather than the actual volume of vocabulary items is the determinant of phonologically structured lexicon then degree of delay in receptive vocabulary will be related to PA. This hypothesis will be tested with deaf participants and hearing participants.

8.3.v Impact of Language Delay on PA in Deaf Participants

Deaf children were matched on vocabulary age using the BPVS age equivalent score. One group of children is relatively less delayed in vocabulary acquisition (V+) than the other group (V-) (see section 8.2 for a participant summary). If degree of delay in vocabulary acquisition is a determinant of PA then the group with relatively less delayed vocabulary acquisition should have superior performance on the 0- PA measures than the V- group. If phonological awareness is determined by **volume** of items in the lexicon, then the two groups should have equivalent phonological awareness.

The means from the phonological awareness tests at T1 are given in table 8.6. Independent t-tests were run to test the significance of differences between the groups. The t value is in column 4. None of the differences were significant.

table 8.6 PA differences Deaf Participants Matched for BPVS Age

	V+	V-	t value
0+ Trials			
Syllable	83.17* (30.6)	86.06* (20.7)	-.187
Rhyme	77.67* (12.5)	72.16* (27.3)	.449
Phoneme	70.33* (18.9)	58.60* (39.7)	.651
0- Trials			
Syllable	81.50* (27.0)	65.00* (25.8)	1.08
Rhyme	80.67* (14.7)	65.17* (22.5)	1.41
Phoneme	48.83 (27.7)	27.00 (27.8)	1.29

standard deviations in brackets

* indicates performance is above chance

A comparison of the 0+ and 0- means shows that the two groups had very similar performance on the 0+ trials, however, there appeared to be a divergence in performance on the 0- trials. The V+ group had superior performance on the trials requiring true phonological awareness as the hypothesis predicts. It is possible that the null finding is due to a Type II error given the small numbers of participants.

Summary – Language Delay and PA in Deaf Participants

It was predicted that there would be a difference in phonological awareness between the two groups of deaf participants who were matched for vocabulary age. The results were in line with predictions, the V+ group had better true phonological awareness than the V- group, however, the difference between the groups was not significant. A difference in means is evident on the incongruent trials (trials where orthographic knowledge could not be recruited to aid phonological judgements). The two groups had similar means on the congruent syllable and rhyme trials, which suggests that there was no underlying systematic difference between the groups that could have explained the difference on the 0+ trials (i.e. did not understand the task). Indeed, non-verbal reasoning was equivalent in the two groups.

8.3.vi Impact of Language Delay on PA in Hearing Participants

In this section, the PA of a group of participants with specific language impairment (SLI) is compared to a group of hearing children matched for vocabulary age (VAM). If degree of delay in vocabulary acquisition is an important determinant of phonological awareness then the SLI group will show deficits in PA relative to a hearing, vocabulary aged matched control group. If, however, the degree of delay is not a critical determinant and then the two groups who are matched for vocabulary age should have equivalent phonological awareness.

Performance Levels on the PA Measures

The means from the phonological awareness tests are given in table 8.7. Given the unequal numbers of participants in the groups, Mann Whitney tests were run to test the significance of differences between the groups. The U and z values together with the associated probability level (p) are in column 4.

table 8.7 PA Performance Comparison (SLI & VAM Groups)

	SLI	VAM	U z p
0+ Trials			
Syllable	61.5* (28)	61.67* (31.9)	52.5 -.11 ns
Rhyme	66* (31.8)	86.1* (22.9)	31.5 -1.65 ns
Phoneme	62.42* (26.6)	83.3* (18.7)	26.5 -2.02* .05
0- Trials			
Syllable	51.8 (32)	54.1 (30.2)	48.5 -.39 ns
Rhyme	70.83* (26.7)	83.2* (23.4)	38.5 -1.13 ns
Phoneme	56.5 (21.4)	85.7* (12.6)	11 -3.08 .001

standard deviations in brackets,

* group significantly above chance

The two groups had equivalent performance on the syllable tests, but neither group was above chance on the 0- syllable trials. Performance on the rhyme task (both congruent and incongruent trials) was higher in the VAM group although the difference between the groups did not reach significance. The younger VAM group had significantly better performance on congruent and incongruent phoneme trials than the SLI group. The hearing SLI group was not above chance performance on the 0- phoneme trials, whereas the younger VAM group was near ceiling on these trials.

Summary

The predicted difference in phonological awareness was significant at the level of the **phoneme**. The VAM and SLI group had equivalent non-verbal reasoning scores so the difference in phoneme awareness cannot be attributed to this factor. The VAM group was younger than the SLI group, therefore, the difference in phoneme awareness cannot be attributed to age. Furthermore, the two groups had equivalent reading ages, therefore advanced phoneme awareness cannot be attributed to higher reading age.

The SLI and VAM groups showed equivalent awareness of syllables. This shows that the SLI group's deficit in phonological awareness, relative to a group of participants at the same vocabulary age, was with intra-syllabic awareness of phonemes.

8.4 DISCUSSION

What are the determinants of phonological awareness in deaf children with cochlear implants?

The hypothesis was that the development of a phonologically structured lexicon would be strongly determined by the timing of vocabulary acquisition. According to Locke (1997), delayed acquisition of vocabulary would significantly inhibit the development of segmentally structured lexicon. It has been inferred that PA tasks are an index of the status of phonological representations. It was predicted that degree of delay in vocabulary acquisition at T1 would be the critical determinant of true phonological awareness in the CI group at T2. Auditory perception (measured by auditory speech perception) might be related to PA, but this relationship would be mediated by vocabulary. Contrary to these predictions the results showed that speech perception was the critical determinant of phonological awareness (of 0- rhyme trials at T2). Furthermore, the significant relationship between vocabulary delay and rhyme awareness was mediated by speech perception.

One possible reason for why a significant relationship between vocabulary delay and phonological awareness was not found in the CI group could be the extent of the delay in spoken language development. According to Locke, insufficient volume of stored utterances at the time when the analytic and computational mechanism is poised for activation will mean that its activation is attenuated. If the mechanism is not fully activated within the critical period, vocabulary acquisition **after** the sensitive period will not alter the extent to which the mechanism is 'turned on'. Vocabulary acquisition after the critical period means that the segmental organisation of the phonological representations (which is based on the computation and analysis of the phonological similarity between words) will always be restricted. If this is the case, then the relationship between vocabulary acquisition and phonological awareness might not be so strong in children where the theoretical analytical and computational mechanism was not fully activated.

Vocabulary delay or vocabulary volume as determinants of phonological awareness

Deaf Participants Matched for Vocabulary Age

Two groups of deaf children were matched on vocabulary age, but the degree of delay in vocabulary acquisition was different. This was done to explore whether **volume** of vocabulary items or **delay** in vocabulary acquisition was related to phonological awareness. It was found that deaf participants with delayed receptive vocabulary had weaker phonological awareness (orthographically incongruent trials) compared to participants matched for vocabulary age who were relatively less delayed in vocabulary acquisition. This result was especially noticeable at the level of phoneme awareness. However, none of the differences reached conventional significance, this was probably due to the small number of participants.

Hearing Participants Matched to SLI Participants on Vocabulary Age

The SLI group and their verbal age matched controls were equivalent on the test of syllable awareness (both congruent and incongruent trials). Both groups were below chance level on the incongruent syllable trials. It has already been suggested in Chapter 6, that the 0- syllable trials required greater phonological sensitivity than the 0+ trials. Furthermore, it was concluded in Chapter 5, that the one-to-one correspondence requirements of the syllable task made it a more cognitively demanding task than the rhyme and phoneme tests. Children with SLI are reported to have difficulties sequencing and co-ordinating motor skills (Hill, 2001). It is plausible that deficits in this domain would cause deficits on the syllable task due to its one to one correspondence demands. Thus, the SLI group performed at a similar level on this task to a group of younger children. The SLI group had weaker rhyme awareness than their verbal matched controls, although this difference was not significant. This suggests that their phonological representations were not as well specified at the intra-syllabic level as younger children matched for vocabulary age. Awareness of phonemes was significantly worse in the SLI group compared to their verbal age matched controls. The inference is that the SLI group's deficit in phoneme awareness is due to weak representations at the level of the phoneme. Thus, whilst the children with SLI had been able to learn new vocabulary, their phonological representations were under specified compared to hearing children who had no history of delayed vocabulary acquisition.

The results from the SLI study shows that timing of vocabulary learning is associated with the degree to which phonological representations become segmentally organised. The cause of the delay in vocabulary acquisition in children with SLI has not been established. It is likely that within the SLI group, participants differed in the pattern of deficits underlying their language learning disorder. Within the time constraints of this study it was not possible to test Locke's hypothesis about the cause of SLI. What has been shown is that hearing children with a history of **lexical delay** showed deficits on the PA tasks relative to a younger group of children matched for receptive vocabulary age. This finding supports the theoretical position that phonological awareness (in particular performance on these tasks of phonological awareness) is not solely determined by auditory perceptual skill (i.e. what can be **heard**) but is also related to language development.

According to Locke's theory chronically delayed vocabulary acquisition (i.e. beyond three years of age) will mean that the analytic and computational mechanism will not be fully 'turned on'. Children who had an insufficient volume of stored utterances within the sensitive period may continue to acquire vocabulary, but their phonological representations will always remain under specified. We have some evidence to support this theory. However, we have seen that children with early lexical delay (caused by deafness or SLI) are able to develop phonological awareness at least of intra-syllabic units (i.e. the rime). These findings suggest that early lexical delay may not totally preclude the development of a phonologically structured lexicon, however, the degree to which the representations can be specified may be restricted to syllabic and sub-syllabic segmentation.

In the next chapter the association between phonological awareness and reading in deaf children with cochlear implants is examined.

Chapter 9 – Phonological Awareness and Reading in CI Children

9.1 INTRODUCTION

There is a strong and predictive relationship between phonological awareness and reading in hearing children (see Chapter 1). Awareness of the internal constituents of syllables (rimes and phonemes) is thought to be important for the mastery of the alphabetic code. Less is known about the importance of phonological awareness to the reading development of deaf children. This question is explored here. Studies reviewed in Chapter 2 showed that syllable and rhyme awareness is usually only evident in deaf adolescents and adults who have relatively advanced reading skills (Olson & Nickerson, 2001; Hanson & Fowler, 1987, etc). This implies that phonological awareness plays a casual role in determining word reading. If deaf children with implants are able to utilise phonological awareness to aid reading development then a relationship should be found between phonological awareness at Time 1 (T1) and reading development at Time 2 (T2). In particular, rhyme and phoneme awareness at T1 might be strongly related to word decoding at T2 because awareness of intra-syllabic units is most strongly related to word decoding in hearing children.

Several studies have shown a strong predictive relationship between vocabulary and reading in deaf children (Moores & Sweet, 1990). In Chapter 8 it was reported that vocabulary level at T1 was related to rhyme awareness at T2. If vocabulary development partially determines phonological awareness, then a relationship between vocabulary and reading in deaf children may partly encompass a link between phonological awareness and reading. On the other hand, the vocabulary age of the cochlear implant users at T1 was around four years. Their age equivalent word decoding score was around seven years. This discrepancy suggests that the CI participants had mastered some of the mechanics of word decoding (i.e. making connections between graphemes and phonological units), which was independent of vocabulary knowledge.

In this chapter the relationship between phonological awareness and word decoding in deaf children is explored. In order to test the specificity of this relationship the possible contribution of other variables to word reading must be considered. If deaf children rely on orthographic strategies to decode words rather than phonological strategies then non-verbal IQ might be related to word reading. The degree to which vocabulary knowledge and speech perception are related to word decoding must also be investigated. Vocabulary knowledge is expected to be predictive of word reading, however, the hypothesis tested here is that phonological awareness is also a determinant of word decoding. If this hypothesis is correct and PA has a unique contribution to the word reading skills of deaf children then the relationship between PA and word reading should emerge as an independent predictor of word reading. This prediction is tested by comparing phonological awareness in two groups of deaf children. If PA is specifically and causally related to word reading in deaf children then children with advanced word reading skills should have superior phonological awareness compared to a group of relatively delayed readers. This should be the case even if the two groups of deaf children have the same vocabulary ages.

Research Questions

1. **Is phonological awareness causally related to word decoding skill in deaf children with cochlear implants?**

   Based on research from hearing children, measures of intra syllabic awareness (rhyme and phoneme) are predicted to be more strongly related to word decoding than syllable awareness.

In order to address this research question we consider only those trials where orthographic knowledge could not be used to aid phonological judgements (orthographically incongruent trials 0-). Phoneme awareness (0- trials) was not above chance in the cochlear implant group at T1 so correlation relationships between phoneme awareness at T1 and word decoding at T2 will be unreliable and will not be considered further. Therefore, the strongest relationship between PA and word reading is predicted to be found with rhyme awareness (0- trials).

Deaf children may read words using a orthographic strategy (i.e. based on visual recognition of the word). This strategy may be sufficient to support word decoding of some words. However, the use of this strategy means that words can only be recognised if the word (i.e. meaning of the word) is known and the child has had sufficient exposure to the word and its associated printed form. This strategy is considered to be a relatively ineffective one compared to the use of a phonological strategy to support word decoding. Given the young age of the deaf children in this study and the fact that their reading is at a relatively early stage it is possible that the word recognition is achieved by an orthographic strategy. We predict that phonological awareness is causally related to word decoding in deaf children even in the early stages of word reading. Therefore, phonological awareness is expected to be more strongly related to **degree of delay** in word decoding (measured by the t score) rather than actual word decoding age (measured by the age equivalent score).

2. **What is the specificity of the relationship between true phonological awareness and word decoding in cochlear implant users?**

The prediction is that superior word decoding will be related to the use of phonological strategies. Therefore, we do not predict a positive relationship between non-verbal IQ and word reading t score (i.e. degree of delay in word reading). It was found in Chapter 8 that non-verbal IQ is not a determinant of phonological awareness, therefore, a relationship between PA and word decoding should remain significant even when IQ is controlled. If deaf children who use cochlear implants rely on an orthographic strategy to read words then non-verbal IQ (which is visual task) may be related to word recognition skill.

Speech perception has already been shown to be a determinant of phonological awareness (orthographically incongruent rhymes) in CI users. However, awareness of phonological units is expected to be a more critical determinant of word reading than perception of speech.

Receptive vocabulary knowledge is predicted to be a strong determinant of word reading in the CI group, however if phonological skills are contributing to the word decoding skills of deaf children then a relationship between vocabulary and word reading should be partially reduced if phonological awareness is controlled.

3. Does phonological awareness differ in good and poor deaf readers?

If phonological awareness is important in developing effective word recognition skills then it is predicted that deaf children with relatively advanced word recognition skills will have advanced phonological awareness skills compared to a group of relatively less advanced decoders. If phonological awareness provides a separate contribution to the mechanics of word recognition then this difference in PA between good and poor readers should remain even when the groups are matched on vocabulary age.

9.2 METHOD

9.2.i Participants

The results from the group of children fitted with cochlear implants (CI) are used to address research questions one and two.

To explore research question three some of the deaf children with hearing aids are included. Within the CI group, it was not possible to form two groups who differed in word recognition skill (based on the actual number of words recognised), but had equal receptive vocabulary ages. Two groups of nine participants were constructed. The participants were matched for vocabulary knowledge using the age equivalent score from the BPVS. Within the pairs there was one participant who was able recognise more words than their partner despite the fact that the participants in each pair had the same raw score on the BPVS test (i.e. they knew the same amount of vocabulary). This led to the construction of two groups. One group has the paired participant with **relatively** advanced word recognition skills (good readers, 'GR') and the other group included the participant who was able to recognise relatively fewer words than his or her vocabulary matched partner (poor readers, 'PR'). The pairs and groups were constructed in this way because of the prediction that vocabulary knowledge would be an important predictor of reading outcome for deaf children. Making vocabulary equal across the two groups has the effect of controlling for vocabulary knowledge so that the unique contribution of phonological awareness to reading can be assessed.

The GR group consisted of 5 participants with severe deafness (SHA), 1 subject with profound deafness (PHA) and 2 participants fitted with cochlear implants (1 early CIE, 1 late, CIL). The PR group consisted of 7 participants from the PHA group, 1 subject from the SHA group and 1 subject from the CIE group. Individual pairs are given in 9.1, showing the match on vocabulary age and the difference in the number of words decoded. Information on the group membership is also provided.

table 9.1 Matched Pairs of Good and Poor Readers

Good Readers			Poor Readers		
BPVS	Words Read	Group	BPVS	Words Read	Group
2.50	29	PHA	2.58	2	PHA
4.00	23	SHA	4.00	9	SHA
4.08	39	CIL	4.42	26	PHA
4.92	58	PHA	4.92	27	CIE
5.50	43	SHA	5.42	26	PHA
5.83	54	SHA	5.75	39	PHA
5.75	60	SHA	5.75	33	PHA
6.67	36	CIE	6.67	24	PHA
7.75	61	SHA	7.75	5	SHA

A participant summary is provided in table 9.2.

table 9.2 Participant Summary - Good and Poor Readers

	CA	Non-verbal Reasoning	BPVS Age	Decoding Age	Decoding t-score
Good Readers	8.47 (1.12)	54.78 (9.12)	5.22 (1.56)	7.89 (1.08)	97.78 (7.12)
Poor Readers	8.36 (1.58)	57.00 (8.00)	5.25 (1.51)	6.58 (.85)	83.78 (13.40)

standard deviations in brackets

By design the only significant differences between the two groups were on word decoding age which is derived from the actual number of words recognised ($t = -2.769$; $p <.05$) and word decoding t score ($t = -2.875$; $p <.01$). The participants in the GR group recognised significantly more words than participants in the PR group. Participants in the GR group were also significantly less delayed compared to standardised norms in word recognition skills than participants in the PR group. The two groups were well matched on chronological age and non-verbal reasoning. It was not possible to match the participants for levels of hearing impairment. There were more children with severe hearing loss in the good reader group and more children with profound hearing loss in the poor reader group.

9.2.ii Measures and Procedures

The experimental measures of PA are described in Chapter 5.
The test of non-verbal reasoning, speech perception measure, word decoding and receptive vocabulary tests are described in Chapter 4.

9.3 RESULTS

9.3.i Is phonological awareness causally related to word decoding skill in deaf children with cochlear implants?

It is predicted that phonological awareness at T1 will be causally related to word decoding at T2 in deaf children with cochlear implants. It is predicted that true rhyme awareness will be a stronger causal determinant of word decoding than syllable awareness. This is because awareness of the internal constituents of the syllable is necessary to decode an alphabetic script. We are unable to test the association between phoneme awareness and word decoding in the CI group because phoneme awareness at T1 was not above chance. Theoretically, however, awareness of phonemes should be a strong predictor of word decoding.

The age equivalent score on the test of word reading is derived from the actual number of words decoded. It is possible for participants to have the same reading age, but different degrees of delay (relative to normative data). If phonological awareness underpins word decoding, then phonological awareness will be more strongly associated with word decoding delay (measured by the t score) than word decoding age.

Association Between PA at T1 and Word Decoding at T2

Pearson's correlations were computed to test the association between syllable and rhyme awareness at T1 (orthographically incongruent trials) and word reading age and word reading delay at T2. The results showed that syllable awareness at T1 was not predictive of reading age at T2 ($r = .158$) or reading delay at T2 ($r = .252$). Rhyme awareness at T1 was significantly associated with reading age at T2 ($r = .587$; $p<.01$ – 1 tailed) and with reading delay at T2 ($r = .591$; $p<.01$ – 1 tailed).

Summary

The results suggest that rhyme awareness is causally related to word reading, but syllable awareness is not significantly related to word decoding. We predicted that rhyme awareness would be more strongly associated with word reading than syllable awareness. Awareness of orthographically incongruent syllable trials was above chance in the CI group at T1, the group mean was around 65% (see Chapter 7). Therefore, failure to find an association between syllable awareness (0-trials) and word reading cannot be attributed to ceiling or floor effects. We now go on to assess the specificity of the relationship between rhyme awareness and word reading.

9.3.ii How specific is the relationship between true phonological awareness of rhyme and word decoding in cochlear implant users?

We have found that awareness of rhyme is associated with word decoding. We now go on to investigate the specificity of the relationship between rhyme awareness and word reading. We will examine the degree to which non-verbal IQ, speech perception and vocabulary knowledge at T1 contributes to word reading outcome at T2. Within each section (non-verbal IQ, speech perception and vocabulary), partial correlations will be used to establish the extent to which these other (possible) determinants of word reading account for the relationship between rhyme awareness and word reading.

Association Between Non-verbal IQ at T1 and Word Decoding at T2

We predicted that non-verbal IQ at T1 would not be significantly related to word decoding delay at T2. A Pearson's correlation was computed to test the association between non-verbal reasoning at T1 (measured by the matrices test) and word reading age and word reading delay at T2. The results showed that non-verbal IQ was related to word reading age at T2 ($r = .484$; $p < .05$ – 1 tailed), but it was not significantly related to word decoding delay ($r = .346$).

Partial Correlation – Controlling for Non-Verbal Reasoning

We have already shown in Chapter 8 that non-verbal IQ is not a determinant of phonological awareness, therefore, holding non-verbal IQ constant is not expected to significantly alter the longitudinal association between rhyme and reading. A partial correlation was computed between rhyme awareness and word reading with non-verbal IQ held constant. The results showed that rhyme awareness at T1 was still significantly related to word reading age at T2 ($r = .508$; $p < .05$) and word reading delay ($r = .527$; $p < .05$).

Association Between Speech Perception at T1 and Word Decoding at T2

In Chapter 8 it was shown that audio speech perception at T1 was a determinant of rhyme awareness at T2 ($r = .754$) in the CI group. This relationship remained significant even when vocabulary age was held constant ($r = .653$). If word decoding skill in CI children is partly dependent on the ability to perceive speech then speech perception at T1 will be related to word decoding at T2. We predict that speech perception will be predictive of word decoding. In order to test this a Pearson's correlation was computed between audio speech perception at T1 and word reading age and word reading delay at T2. The results showed that the association between speech perception at T1 was significantly associated with word reading age at T2 ($r = .592$; $p < .01$, 1-tailed), and with word reading delay at T2 ($r = .663$; $p < .001$, 1- tailed).

Partial Correlation – Controlling for Speech Perception

Given the fact that speech perception was a determinant of rhyme awareness the relationship between rhyme awareness and word decoding might be mediated by speech perception. However, we predict that awareness of rhyme will be the more important predictor of word decoding than speech perception. In order to assess this a partial correlation (holding speech perception constant) was computed between rhyme awareness at T1 and word decoding at T2. The results showed that rhyme awareness was significantly associated with word decoding delay ($r = .736$; $p < .01$, 2-tailed), but not significantly related with word decoding age ($r = .362$) when speech perception was held constant.

The strength of the correlation between rhyme awareness and word decoding (t score) actually increased when speech perception is held constant. This supports the view that rhyme awareness is a more critical determinant of word reading than speech perception. If this is correct then the relationship between speech perception and word decoding should reduce if rhyme awareness is held constant. A partial correlation was computed. The results showed that the relationship between speech perception at T1 and word reading at T2 reduced when rhyme awareness is held constant (speech perception and reading age, $r = .400$; ns, 2-tailed), (speech perception and reading delay, $r = .580$; $p < .05$, 2-tailed).

Association Between Vocabulary at T1 and Word Decoding at T2

Based on evidence from the previous research, vocabulary knowledge (measured by receptive vocabulary age) is predicted to be a strong determinant of word reading. A Pearson's correlation was computed between receptive vocabulary age at T1 and word decoding (age and t score) at T2. The results showed that there was a highly significant association between vocabulary age and word reading age ($r = .831$; $p < .001$) and word reading delay ($r = .823$; $p < .001$) at T2.

In Chapter 8, we found a significant correlation between vocabulary age and awareness of rhyme ($r = .590$). Therefore, the relationship between rhyme awareness and word decoding might be strongly mediated by vocabulary knowledge. Given the high correlation between vocabulary and word reading the reduction of the association between rhyme and word decoding following the partial correlation is expected to be large. A partial correlation controlling for vocabulary age was computed with rhyme awareness at T1 and word decoding at T2 (age and t score). The results showed that when vocabulary knowledge was held constant the relationship between rhyme awareness and word decoding was reduced and no longer significant (rhyme and t score, $r = .201$) (rhyme and reading age, $r = -.142$).

If awareness of rhyme contributes to word decoding skill, then controlling for rhyme awareness should partially reduce the correlation between vocabulary and word decoding. A partial correlation was computed, holding rhyme awareness constant. The results showed that vocabulary age at T1 was still strongly associated with word decoding at T2 (vocabulary and reading age, $r = .731$) (vocabulary and t score, $r = .719$). The strength of the association between vocabulary and reading was only minimally reduced.

Summary

Rhyme awareness at T1 was significantly related to word decoding at T2 (both age and t-score). This relationship remained significant when non-verbal reasoning and speech perception were held constant. Rhyme awareness appeared to be a stronger predictor of word reading than speech perception. Overall, the strongest determinant of word decoding at T2 was vocabulary knowledge. If vocabulary knowledge is a determinant of phonological awareness, then it may be that emerging phonological skills are not sufficiently autonomous from receptive vocabulary to support independent correlations with word decoding. One way to test this explanation is to look at differences between children who are matched for vocabulary age but who have differing word recognition skills.

9.3.iii Does phonological awareness differ in good and poor deaf readers?

If phonological awareness makes a unique and causal contribution to word recognition then deaf children with relatively good decoding skills will have advanced phonological awareness compared to poorer decoders. So far we have found that rhyme awareness is associated with word decoding in deaf children who use cochlear implants. This suggests that rhyme awareness rather than syllable awareness is related to reading in deaf children. If this is true, then the two groups of readers (relatively good readers and poor readers) should differ most markedly on rhyme awareness.

PA Performance Levels Good and Poor Readers

The means for the phonological awareness measures are in table 9.3.

table 9.3 PA Performance– Good and Poor Readers

	S 0+	S 0-	R 0+	R 0-	Ph 0+	Ph 0-
Good Readers	86.22* (11.14)	69.11* (32.43)	89.78* (11.62)	87.11* (19.07)	73.00* (24.64)	62.00* (21.89)
Poor Readers	71.56* (29.17)	56.78 (34.12)	62.11* (21.26)	60.11* (19.49)	53.22 (26.10)	38.89 (17.86)

* above chance performance (1-tailed)
standard deviations in brackets

The GR Group were above chance on all the PA measures. The PR Group was above chance on the two rhyme measures and the orthographically congruent syllable trials, but not on either of the phoneme trials or the orthographically incongruent syllable trials. In all cases, the means from the PR group were below that of the GR group. Box plots showed that there were two negative outliers in the GR group (0- rhyme and 0+ syllable tests) and one negative outlier in the PR group (0+ phoneme test).

Test For Group Differences in PA

In order to test the significance of the observed differences between the groups, Mann Whitney U tests were computed. The non-parametric test was chosen because of the existence of the 3 extreme scores. The results are presented in table 9.4.

table 9.4 Group Differences PA

Experimental Measure	Mann-Whitney U test		p
S 0+	U = 30.5	z = -.895	ns
S 0-	U = 31.0	z = -.852	ns
R 0+	U = 10.5	z = -2.7	.01
R 0-	U = 10.5	z = -2.68	.01
P 0+	U = 21.5	z = -1.692	ns
P 0-	U = 17.5	z = -2.04	.05

p values are 2-tailed

The good readers had significantly better rhyme and phoneme awareness than the poor readers. The two groups did not differ significantly on syllable awareness, but differed significantly on measures of intra-syllabic awareness.

Summary

The findings are in line with predictions; deaf children who were relatively skilled word readers had significantly better phonological awareness skills than poorer readers. The children in the two groups had the same receptive vocabulary, but the good readers were able to make phonological judgements at the intra-syllabic and phonemic level.

The equivalency in group age and non-verbal reasoning means that the differences in PA performance levels and word reading cannot be attributed to these factors. In accordance with Locke's theory we would suggest that the most likely cause of the difference in phonological awareness between the groups is related to the timing of the onset of the vocabulary burst. The participants were matched for vocabulary knowledge and they were similar ages, so the current degree of delay in vocabulary acquisition is equivalent across the groups. Unfortunately, we have no longitudinal data to test the hypothesis that the timing of the vocabulary burst is responsible for the difference in phonological representation. In the absence of this data and based on the data that is available perhaps the most likely candidate to explain the difference in PA is auditory capacity. The majority of participants in the GR group were severely deaf, the majority in the PR group were profoundly deaf.

9.4 DISCUSSION

It was predicted that phonological awareness would be related to word decoding in deaf children with cochlear implants. The results presented here partially confirmed predictions showing that awareness of rhyme was related to word decoding. It is likely that the pattern of association found between the awareness of phonological units and word reading reflect the developmental level of phonological awareness in the CI group.

Syllable Awareness and Reading

Awareness of syllables was above chance in the CI group, but the task used to assess word reading did not probe the use of syllable awareness in word decoding sufficiently to detect any causal relationship. In general, the CI participants were not advanced readers and the majority of the words read from the BAS test of word reading were mono-syllabic. If syllable awareness is causally related to word decoding, then a test of multi-syllabic word reading would be a more appropriate test to use to investigate the significance of an association. Whilst this explanation might partially explain the reason for the null finding of a relationship between syllable awareness and word decoding in the CI group, in order to accurately decode words in an alphabetic script awareness of intra-syllabic units is required.

We found that non-verbal reasoning was positively related to reading age, but not to the reading t score. This suggested that deaf children using implants rely to some extent on orthographic strategies to read words (i.e. by visual recognition). However, the fact that superior non-verbal IQ was not associated with the reading t score suggests that the use of a primarily orthographic strategy is limited in terms of supporting word decoding. The association between rhyme awareness and the reading t score suggests that that enhanced phonological sensitivity underpins the development of word decoding skills in deaf children.

Vocabulary Knowledge as a Determinant of Word Reading

The association between rhyme awareness and word reading in the CI group seemed to be strongly mediated by receptive vocabulary. Vocabulary knowledge at Time 1 was a strong determinant of word reading at Time 2. However, the results from a comparison of good poor deaf readers who were matched for vocabulary age, showed that word reading is not only determined by vocabulary knowledge in deaf children. The good and poor readers had the same level of receptive vocabulary, but they differed on the number of words read and in the degree of delay compared to hearing norms. The hypothesis is that the difference in the number of words read is due to better phonological awareness. The good readers did have advanced phonological awareness compared to the poor readers, especially for the orthographically incongruent rhyme and phoneme trials. The discrepancy between vocabulary knowledge and word reading age equivalent scores in the CI group suggested that the CI children had begun to master some word decoding skills (i.e. grapheme/phoneme conversion). It is possible that the discrepancy in age equivalent scores between the two tests might be misleading, resulting in an overestimation of the degree to which word decoding skills were established in the CI group. Further understanding of the word decoding skills of the CI group could have been achieved by using a test of non-sense word reading. Alternatively, the degree to which vocabulary knowledge determined word reading on the BAS test could have been investigated by devising a receptive vocabulary test (using pictures) of the words used in the word recognition test.

CONCLUSION

Phonological awareness, especially of intra-syllabic units, is necessary for learning to decode an alphabetic script. However, the case of dyslexic children (see Chapter 1) shows that a level of functional literacy skills can be achieved by relying on contextual/comprehension strategies and orthographic recognition. Furthermore, some good deaf readers are able to derive meaning based on context. The major problem facing the majority of deaf children is that their knowledge of language is insufficient to support a context/comprehension strategy to support reading comprehension. So, even if visual recognition and visual memory could be utilised to bypass the phonological route to word **decoding** the language deficits common in deaf children thwarts development of general literacy attainment. The findings presented so far suggest that increased auditory capacity afforded through the use of a cochlear implant supports phonological awareness and if deaf children possess phonologically structured lexicon they are likely to make connections between print and abstract speech units that will support their decoding skills. It was found that the phonological awareness skills of the CI group developed over time (Chapter 5 and Chapter 7). Therefore, in the future, it seems likely that the emerging phonological awareness of the CI users will be sufficient to support the development of phonological strategies to aid word reading. If slow encoding acts as a barrier to higher levels of representation (Wood, 1988) then any improvement in the mechanics of reading will impact in a meaningful way on the development of literacy for deaf children.

Chapter 10 - Discussion

10.1 INTRODUCTION

The aim of this thesis was to assess the development of phonological awareness in deaf children who use cochlear implants. The fitting of a cochlear implant provides greater access to the intensity range and frequency spectrum within which the speech sounds of language are present. The ability to perceive speech is enhanced by the use of a cochlear implant (see Chapter 3). This concrete improvement in the ability to hear speech sounds should make it easier for deaf children to develop abstract categories based on the phonological units of the language. In this thesis I have argued that the development of phonological representations and the ability to show awareness of sounds in words is not **only** determined by the ability to 'hear' speech. Whilst the ability to hear speech is an important requirement for the development of spoken language, I have argued that the phonological structure of the representations can only emerge as the child learns language. It is possible to perceive speech sounds (i.e. hear consonants and vowels) and use language, but have poor underlying awareness of the phonological units of the language as in the case of dyslexic children. I have argued that the derivation of phonological knowledge comes about as a result of vocabulary acquisition. Locke (1997) argues that the rapid increase in vocabulary acquisition during the vocabulary burst is responsible for the instantiation of a theoretical mechanism which is responsible for the computation and analysis of patterns that occur in the language. According to Locke if the brain is not put under pressure at the right time (i.e. either because of delayed onset of language learning or insufficient volume of items stored within the sensitive period) then the theoretical mechanism will not be fully functional. Holistic phonological representations cannot support awareness of the internal constituents of words whereas fully segmented phonological representations at the level of the phoneme will give rise to phoneme awareness. Deaf children with cochlear implants are better able to hear speech sounds, but what impact does that have on the development of phonological knowledge?

The main focus of the thesis was the investigation of the developmental pattern of phonological awareness in deaf children with cochlear implants. I have argued that the timing of language learning will affect the degree to which phonological knowledge develops. A number of research questions have been presented in this thesis. The five main research questions of this thesis are;

1) What is the developmental trajectory of phonological awareness in deaf children with cochlear implants?

2) Is there an effect of timing of implant fit on phonological awareness?

3) Is there a benefit of cochlear implant on phonological awareness?

4) What are the determinants of phonological awareness in children with cochlear implants?

5) Does phonological awareness support word recognition in deaf children with cochlear implants?

A prospective, short term longitudinal study involving deaf children with and without cochlear implants, hearing children at the same reading level and chronological age as the CI group and hearing children with a history of language delay was undertaken. A new computerised battery of assessments of phonological awareness was designed in order to assess the degree to which phonological representations were segmentally organized.

The main focus of this chapter is to discuss the implications of the results reported in this thesis on the hypothesis regarding the determinants of phonological awareness. An important aspect of that discussion involves a consideration of the methodological factors that impacted on the significance of the experimental findings both in terms of the theoretical framework and the clinical significance of the findings. Finally, I will make suggestions for future research. This chapter begins with a summary of the experimental findings.

10.2 Summary of The Experimental Findings

10.2.i Does phonological awareness in cochlear implant users follow a developmental pattern?

Previous research with hearing children shows that phonological awareness is influenced by the hierarchical status of the constituents of the syllable (Treiman & Zukowski, 1996). Awareness of syllables develops first, followed by intra-syllabic awareness of onsets and rimes and then awareness of individual phonemes develops. It is suggested that hearing children's awareness of sounds in words and ability to manipulate sounds in words reflects the degree to which their own speech based representations are specified (Snowling & Hulme, 1994; Swan & Goswami, 1997). The hypothesis was that deaf children's phonological awareness would also follow this developmental pattern. The predictions were that awareness of syllables would precede rhyme awareness and awareness of rhyme would precede awareness of phonemes.

There was evidence of this developmental pattern of phonological awareness in the CI group. At Time 1, syllable awareness was easier than rhyme awareness, rhyme awareness was easier than phoneme awareness, phoneme awareness was not significantly different to chance (Chapter 5, Section 5.3.i). The tests of PA were designed so that the cognitive demands were low and equal across the three tests. Therefore, the difference in performance levels (also supported by reaction time data - Chapter 5, Section, 5.3.iii) cannot be attributed to differing task demands. In addition, there was an improvement in phonological awareness over time in the CI group and the pattern of improvement supported the developmental prediction showing that intra-syllabic awareness developed prior to phonemic awareness (Chapter 5, Section, 5.3.vi). This pattern of development was also evident when individual performance patterns were evaluated (Chapter 5, Section 5.3.ii).

The PA tests were designed so that half of the trials in each test were orthographically incongruent (0- trials) which meant that only phonological sensitivity could have yielded a correct response. These trials required true (non-orthographic) phonological sensitivity. When individual performance was analysed according to orthographically congruent and incongruent trials the same developmental pattern emerged (see Appendix D for T1 and T2 for individual data). True phonological awareness of syllables (S0-), preceded phonological sensitivity to rhyme (R0-) which came before true phoneme awareness (P0-). One of the most interesting findings showed that awareness of phonemes was particularly difficult for cochlear implant users to achieve. At Time 1 none of the children in the study were able to show true phoneme awareness (one participant 'dj' hovered around the pass mark at T1 on this test, but was below the cut off at T2) . Twelve months later, a third of the sample were able to show true phoneme awareness. These were all children who had been either fitted with their implants early or who had developed a significant amount of spoken language prior to the fitting of the implant (Appendix D).

Taken together these group findings at T1 and T2, the pattern of development from T1 to T2 and the corresponding individual patterns of performance support the prediction that phonological awareness in the CI group followed the trajectory found in hearing children. Perhaps the fact that phonological awareness developed over time suggests that phonological knowledge in CI children is **delayed** rather than being represented differently to hearing children. Phoneme awareness was not characteristically achieved by the CI group even at Time 2, but if true phoneme awareness develops in cochlear implant users, then it will emerge from a foundation of larger units (syllables and rimes).

10.2.ii Is there an effect of timing of the implant fit on phonological awareness?

It was predicted that the **early** fitting of a cochlear implant would enable early acquisition of spoken receptive vocabulary which in turn would support the development of segmented phonological representations. In the same vein, deaf children who developed spoken language at an early age using hearing aids were expected to show the same advantage. Work by Charlier and Leybaert (2000), reported in Chapter 2, strongly supports this theoretical view. They found that cued speech only supported rhyme awareness when it had been used with deaf children from an early age. Children exposed to the same unambiguous phonological input later in childhood had no such advantage. Their rhyme awareness skills were the same as deaf children who had never been exposed to cued speech. The only group of deaf children who had age appropriate rhyme awareness were those who were exposed to cued speech early in life. This is the only study to have shown that deaf children can develop age appropriate phonological awareness. It is clear from Charlier and Leybaert's study that the clarity of the input is not the only determinant of phonological representation, but that the timing of the input is a crucial factor.

Overall, the difference between the two groups of CI participants (early versus late) on the phonological awareness measures was small. The only significant difference found was in the ability to make true phonological judgements (i.e. where orthographic knowledge could not be recruited to aid phonological decisions) at Time 2 (Chapter 7.3.viii). It was found that children fitted early were significantly better at making true rhyme judgements than children fitted later. There was an indication that the ability to make true phoneme judgements was also better in the children fitted early. The difference between the groups on phoneme awareness was not significant, however, the only children fitted late who achieved phoneme awareness at T2 were two of the three children who had developed a significant amount of spoken language prior to implant fitting using conventional hearing aids (see Appendix D).

The issue of **timing** of vocabulary acquisition was examined by carefully matching two small groups of deaf children for receptive vocabulary age, such that one group had significantly greater delay in vocabulary knowledge than the other group (Chapter 8, Section, 8.3.v). If the timing of vocabulary acquisition is important for the development of a phonologically structured lexicon then the group with less delay in receptive vocabulary should have more advanced phonological awareness than the group with greater delay. The results were in line with predictions, but the differences between the groups were not significant. This may have been due to the small number of participants in each group (n=6).

Overall, the pattern of results indicate that **early** acquisition of spoken language does impact on phonological awareness. However, several factors must constrain any conclusion on the timing of implant fitting from the results presented in this thesis. Crucially, the children in the early and late groups were not equivalent in terms of the duration of implant use. Children in the late group were less experienced implant users than children in the early group (see Chapter 4). Duration of use with an implant correlated with rhyme awareness, but only for children who had been fitted early (see Appendix B and C). The small numbers of CI participants means that conclusions from correlational analyses must be made with caution. Perhaps there is an indication here that children fitted early gained more benefit from **continued** CI use than children fitted later. In order to be certain that the differences (albeit small) in PA between the two CI groups is due to the timing of the implant fit rather than the duration of CI use, the two groups should have been matched for duration of CI use. Ideally, the deaf children in the vocabulary matched groups should have had equivalent degrees of hearing impairment, but it was not possible to achieve this precisely. If the question regarding the timing of language acquisition is to be adequately addressed in future studies more detailed information, including reliable evidence on early language development of participants, is required.

10.2.iii Is there a benefit of CI on phonological awareness?

In line with previous CI research methodology a benefit of CI was inferred if the PA skills of the CI group were equivalent to a group of profoundly deaf children making good use of residual hearing with conventional hearing aids. This was the benchmark group. However, given the changing expectations and more recent research findings which suggest that children fitted with implants are similar to children with severe hearing impairment. The CI group were also compared to severely deaf children using hearing aids. A comparison was also made with two groups of hearing children. One group was matched to the CI group on reading age and a second group was matched on chronological age.

Overall, the CI group had equivalent phonological awareness of syllables, rhymes and phonemes to the group of profoundly deaf children using hearing aids (Chapter 6, Section 6.3.i). Syllable awareness in the CI group was equivalent to a group of severely deaf children using hearing aids. However, there was no difference on the syllable test between the profoundly and severely deaf groups and this might suggest that the enhanced auditory perceptual capacity afforded through the implant was not necessarily the reason for enhanced syllable awareness. Performance on the syllable task in the CI group was equivalent to younger hearing children at the same reading level **and** children of the same chronological age (Chapter 6, Section 6.3.iii). When performance on the orthographically incongruent syllable trials was examined it was found that the CI group's syllable awareness was not based solely on orthographic knowledge, in fact there was no difference in performance levels on the syllable task between the CI group and their hearing chronological age matched comparison group (Chapter 7, Section 7.3.ii). These results show that the CI group had age appropriate syllable awareness.

Performance levels on the rhyme and phoneme tasks were lower in the CI group compared to the children with severe hearing impairment (Chapter 6). There was also a significant difference between the CI group and the severely deaf group when it came to making true phonological judgements about rhymes and phonemes (i.e. independent of orthographic knowledge) (Chapter 7, Section 7.3.iii and iv). The CI group had lower performance levels on these tests than the severely deaf group. Comparisons between the CI group and the two groups of hearing controls showed that rhyme and phoneme awareness in the CI group was significantly lower than children of the same age and younger children matched for word reading ability. In summary, the results of the CI group compared to the hearing control groups yielded very similar results reported in previous studies of deaf children (non-CI users with severe to profound hearing impairment, i.e. 75 dB HL to 120 dB HL). Awareness of syllables was equivalent to hearing controls, but rhyme and phoneme awareness was significantly delayed. Cochlear implant fitting does not restore normal hearing. In very profoundly deaf children the fitting of an implant enhances auditory capacity so that it is equivalent to children with a severe-to-profound hearing impairment (i.e. around 90 to 95 dB HL) (see Chapter 3). All children in the CI group had significant language delay at the time of the implant fitting and at the time of the study. Therefore, it was predicted that the CI group would show a similar degree of difficulty with rhyme and phoneme awareness when their performance was compared to hearing children as has been reported in previous studies. The role of residual hearing in the development of PA in deaf children has not been a major focus in prior studies. In order to infer a benefit of CI on PA it is essential to compare the CI users to a group of children with equivalent hearing loss (i.e. children with very profound hearing impairment who use hearing aids). In the current study it was not possible to recruit such a group and the previous research has not reported PA performance in deaf children according to degree of residual hearing. The results from this study show that PA in CI users is equivalent to less profoundly deaf children who use hearing aids, but that awareness of syllables was equivalent to severely deaf children. If a direct link between auditory perception and PA existed then a stronger benefit of CI on intra-syllabic and phonemic awareness might have been predicted because theoretically CI use means that all speech sounds can be perceived. However, in this thesis I have argued that phonological awareness represents a higher more abstract level of knowledge, that it develops over time as a function of language learning and is not **solely** dependent on audition.

10.2.iv What are the determinants of phonological awareness?

An experimental hypothesis of this thesis was that delayed language development affects the development of phonological knowledge. Auditory perception was considered to be an important determinant of PA, but not the sole determinant. Overall, the evidence from the correlations reported in Chapter 8 showed that auditory capacity (measured by speech perception and degree of hearing impairment) was the strongest predictor of performance on the phonological awareness tests. When the determinants of PA in the CI group at Time 2 were explored it was found that speech perception at Time 1 was a much stronger predictor of true rhyme awareness than receptive vocabulary. Further, the difference between the profoundly and severely deaf children (hearing aid users) on the PA tasks suggested that degree of residual hearing was related to awareness of intra-syllabic units (rime and phoneme), but was not to awareness of syllables. (The severely deaf group were had better performance on the rhyme and phoneme tests than the profoundly deaf group – Chapter 6, Section 6.3.i).

A further way in which the link between language and PA was tested was by comparing two groups of hearing children. One group had a history of early language delay and persistent language impairment (SLI) the other group of hearing children was matched to the SLI group on language age. The results from this analysis showed that the SLI group was significantly impaired relative to the comparison group on phoneme awareness. In fact, their performance on the phoneme trials that required true phoneme sensitivity (orthographically incongruent trials) was not significantly above chance (Chapter 8, Section 8.3.vi). The overall performance level of the SLI group on these phoneme trials was 56.5% which is very similar level to that achieved by the group of deaf children with severe hearing impairment (60.8%). The ability to draw firm conclusions regarding the determinants of phonological awareness from these data must be constrained by the sample sizes involved. However, based on the pattern of findings from the SLI analyses, performance on the phonological awareness tests is not purely dependent on auditory perception. The results from the SLI study also give further weight to the hypothesis that delayed lexical acquisition impacts on the development of phonological awareness.

10.2.v Does PA support word recognition in deaf children with cochlear implants?

The role of phonological awareness in the word recognition skills in CI users was explored in Chapter 9. It is acknowledged that deaf children can use contextual strategies to derive the meaning of unfamiliar words when reading text. This strategy appears to be characteristic of advanced deaf readers who have good language skills. It is undisputed that in order to derive meaning from print, the use of context is essential and is a strategy used by both deaf and hearing readers. In this thesis the interest is the processes by which deaf children decode or recognise individual words. If a cochlear implant benefits phonological awareness and if deaf children can benefit from using a phonological approach to decode words then an improvement in PA should support word recognition.

A significant longitudinal correlation between rhyme awareness at Time 1 and word decoding at Time 2 was found in the CI group. This relationship seemed to be mediated by the strong relationship between vocabulary knowledge and reading (Chapter 9, Section 9.3.i). Given the fact that the reading task only probed word recognition of single words the mediation between rhyme awareness, vocabulary and reading cannot be due to a 'semantic bootstrapping' strategy since context could not be used to derive the word. Given the small numbers of participants it was not possible to use regression analyses to find out whether PA had a unique contribution to word recognition. Ideally, a test of non-word reading should have been included in order to investigate the extent to which deaf children were able to utilise a phonological approach to decode unfamiliar words (this is further discussed in Chapter 9). In order to investigate the degree to which phonological awareness made a unique contribution to word recognition two groups of deaf children were matched for vocabulary age (Chapter 9, Section 9.3.iii). One group was able to read more words than the other group, but the two groups had equivalent vocabulary ages. If phonological awareness is responsible for the relatively advanced word recognition skills of the 'good reader' group then the children who read more words should have advanced phonological awareness compared to the children who read fewer words. This was the pattern found. There was a significant difference in phonological awareness of intra-syllabic units (rimes and phonemes) between the two groups of deaf children. This suggests that the children who were relatively advanced word readers were using a phonological strategy to read words.

As noted the CI group had significantly delayed phonological awareness of intra-syllabic units compared to younger hearing children who were matched for word reading level (Chapter 6, Section 6.3.iii). This suggests that the CI group achieve the same end state as the hearing group, but via a different route. We might assume that in this single word reading task the deaf children adopted a visual recognition approach perhaps akin to the logographic strategy found in younger hearing readers. There is no direct evidence to support this assumption. Information from the teachers of the CI group suggested that the children were likely to attempt to decode unfamiliar words using grapheme/phoneme correspondence rules. There was some evidence of this during the word reading task. Some children made what could be described as phonologically related errors (i.e. saying 'swing' when presented with the target 'ring') although these error types were not characteristic of all the children in the study. Errors such as these show that the CI participants can be sensitive to the relationship between graphemes and phonemes and that they can attempt to decode words using a phonological approach.

One theoretical possibility is that the developing awareness of intra-syllabic phonological units found in the CI group could be used pedagogically to support word decoding. Hearing children appear to be sensitive to the regularities in rhyme orthography and they can use this knowledge to read new words (Goswami & Bryant, 1990). The link between graphemes and phonemes might need to be made more explicit for deaf children since the underlying phonological representation is likely to be partial and delayed compared to hearing children of the same age. This raises several outstanding empirical questions. Given the relative ease of derivation of information through the visual modality perhaps more emphasis should be given to developing visual-orthographic strategies in order to scaffold knowledge of the underlying phonological units. Given the central role of language in the reading attainment of deaf children, should reading instruction focus on making explicit links between letters and sounds or should reading be delayed until language levels are sufficient to support text comprehension?

10.3 Clinical Implications

The following section outlines possible clinical implications arising from the experimental findings.

10.3.i Developmental Pattern of Phonological Awareness

The most robust result in this thesis is that the developmental trajectory of phonological awareness in the CI group followed the predicted sequence. Young deaf children are able to show awareness of sounds in words. There is an indication that deaf children attempt to decode words by applying grapheme/phoneme correspondence rules and so increased phonological awareness may make an independent contribution to the word reading skill of deaf children. These findings have a number of potentially important pedagogical implications. If PA does have a contribution to make in word reading then it is likely that teachers will need to make the link between graphemes and underlying phonological units explicit for deaf children. The pattern of findings with respect to the orthographically congruent trials being mastered prior to orthographically incongruent trials at each linguistic level (Appendix D) suggests that the best teaching strategy would use orthography to scaffold phonological development. Furthermore, it seems intuitive that the level of instruction should be related to the child's underlying level of phonological awareness. This thesis has shown the importance of assessing phonological awareness using tests where the developmental sequence is predicted. Adopting this approach lead to the design of developmentally orientated tests. The results show that phonological awareness in CI users follows the predicted developmental sequence. If our assessment had been pitched at the end state (i.e. phoneme awareness) then the developmental pattern would have been lost. The importance of phoneme awareness for reading and the link between phonemes and speech intelligibility means that sometimes teachers and therapists focus on the phoneme level without considering earlier linguistic levels. Assessments carried out by teachers and speech and language therapists should be developmentally organised (i.e. syllable, rime, phoneme) to ensure that emerging phonological awareness is identified and used as a platform from which further developments are supported. The efficacy of different phonological training strategies for the remediation of reading in deaf children is an outstanding empirical question.

10.3.ii Timing of Implant Fitting

The age at which children are fitted with a cochlear implant is reducing. In response to research evidence showing the efficacy on speech perception of early fitting, some paediatric implant programmes have taken the decision not to fit implants to children over the age of five years. The findings from this study show that some children fitted with implants after the age of five years achieve similar outcomes to those fitted at a younger age. Furthermore, as a group, the children fitted later with implants actually had faster rates of vocabulary acquisition between Time 1 and Time 2 than children fitted early (Chapter 4). These findings suggest that cochlear implant fitting after the age of 5 years still provides significant benefit to the child because their rate of vocabulary development over a twelve month period (1 year 4 months) was much higher than that which would have been predicted with the use of conventional hearing aids (between 5 and six months in one year). Whilst I have argued that early development of spoken language is important for outcome post cochlear implant fitting, some children fitted later still made significant gains.

10.4 Limitations of the Study

In line with current methodology in the CI field it was decided to investigate the benefits of implants by comparing the CI group with other groups of deaf and hearing children. The relevance of the standard developmental psychological approach to the developmental investigation of deaf children is open for debate (Marschark & Everhart, 1997). There is an increasingly prominent view that the development of deaf children's cognitive, communicative and language development is different to hearing children and this has lead some to question the validity of comparisons of deaf and hearing children (Marschark, 2000). As discussed in Chapter 1, similar issues are also being debated in the general field of cognitive psychology (Karmiloff-Smith, 2001). It is right to acknowledge these perspectives. In the future, theoretical models that explain the course of development in a way that accounts for individual variation both in typical and atypical populations may give rise to a new methodology. Perhaps this will mean that questions about causes of variability within and between special groups can be better identified.

The main methodological limitation of this study is the small number of participants, both cochlear implant users and hearing aid users. The small number of cochlear implant users was largely due to a constraint by GOSH on the involvement of other large cochlear implant centres. The strict inclusion criteria further limited the available sample of CI users and hearing aid users. This strict criteria was intended to limit heterogeneity in the group. All of the deaf children in the study were congenitally deaf, they were all good users of their devices and none of them had additional general learning difficulties or used another oral language apart from English. However, we were not able to control factors such as the amount of rehabilitation or the extent to which children were supported at home. It is likely that these factors contributed to variability between deaf children, but we have no direct evidence that they caused it. Despite having small numbers of participants, the sample represents nearly 60% of CI users who met the criteria for entry to the study. A problem with having small numbers of participants is evaluating the significance of individual variability. When necessary non-parametric statistics were used to ensure that the wide variability in performance did not distort the significance of the results. However, when the sample size is small there is an opportunity to examine individual results.

The absence of a sensitive measure of spoken vocabulary knowledge for use with deaf children was another important factor that has limited the extent to which the role of vocabulary knowledge in the development of phonological awareness could be probed (discussed in Chapter 4). In addition, in order to show that a relatively large volume of vocabulary was acquired rapidly, longitudinal assessment and reassessment of language at short intervals is required. A reliable assessment for such a purpose is the MacArthur Communicative Development Inventory (CDI) (Fenson, et al 1993). The CDI is a parent report diary designed to assess the comprehension and expression of words and gestures from 8 months of age. This assessment has been proved to be a reliable measure of early language and has been used by Bates and her colleagues (Bates & Goodman, 2000) with typically developing children and children with developmental disorders. Willis and Edwards, (1996) used the BPVS and the MacArthur to describe the language development of one deaf child post implant fitting. They found that the BPVS was insensitive to the growth in receptive vocabulary reported by the parents using the CDI. The use of the MacArthur CDI prior to CI fitting could be an excellent addition to the pre-CI assessment in CI centres. Any research investigating the spoken language development of children post CI fitting would benefit from the availability of reliable data on language development prior to CI fitting and post CI fitting.

In our tests of PA the child made a judgement after **listening** to the items as they were named by the experimenter. We chose to name the items used in the tasks for two important reasons. Firstly, whilst we took care to choose items that would be highly familiar to young children, we had no way of guaranteeing that all the words would be known by very young profoundly deaf children. Other researchers have by-passed this problem by screening participants on the words used and excluding those who were unable to accurately name all the items. Given the small number of consenting participants, we were not in a position to exclude any children on this basis. In fact, this would have resulted in only a handful of participants being included because even the most linguistically advanced deaf children (including all the hearing aid users) were unable to correctly identify **100%** of the items in the receptive vocabulary pre-test. This suggests that even if it had been possible to exclude children who were unable to correctly identify all the items this would have made the sample unrepresentative of the population. Secondly, not naming the items would mean that the participants would need to rely heavily on short-term memory to complete the tasks. This might have made the cognitive demands of the tasks too difficult for young deaf children and this could have lead to an underestimation of their phonological awareness. In order to be completely confident that PA tasks measure the degree to which the child's **own** phonological representations are structured the ideal test administration is where items are **not** named by the experimenter. For the reasons given above, this administration procedure was not chosen.

Summary

Perhaps the biggest challenge facing those who wish to carry out experimental research in the cochlear implant field is to recruit a large number of participants without compromising the study design. It is likely that this will only be achieved by conducting multi-centre research. The previous CI research where large numbers of participants are included is based on outcomes from data collected as part of normal clinical procedures. The numbers of participants in these studies is large, but this has sometimes been at the expense of the study design (i.e. wide range of chronological age, or of age of fitting with the implant, or of age of onset of deafness). If one wishes to explore the causal mechanisms affecting development in children then it is necessary to limit the range of chronological age of the participants. In this study, interpreting the significance of the benefit of early cochlear implantation on vocabulary acquisition and reading level was complicated by the difference in chronological age between the two groups.

10.5 Directions for Future Research

In this final section ways of extending the experimental findings reported in this thesis are considered.

Understand Pre-Requisites of Phonological Awareness

In order to extend our understanding of the development of phonological awareness in deaf children it is necessary to explore the origin of the formation of phonological representations. It would be developmentally appropriate to investigate the way in which deaf infants learn about word boundaries. Tests could be based on Peter Jusczyk's theories about the cues in the speech stream that infants use to locate word boundaries (Jusczyk, Cutler and Redanz, 1993a; Jusczyk, Friederici, Wessels, Svenkerud & Jusczyk, 1993b, Jusczyk, Luce & Charles-Luce, 1994). This question could be addressed in a longitudinal study in which infants were tested before and after the fitting of a cochlear implant. It would be predicted that the fitting of an implant would improve discrimination of acoustic cues (such as prosodic cues, presence of aspiration and phonotactic sensitivity) and that these abilities would be related to later vocabulary acquisition.

Understanding Rhyme Awareness

There is some evidence that deaf children may find it easier to represent initial phonemes rather than final phonemes (due to greater saliency of lip patterns for sounds at the beginning of words and more allophonic variation of phonemes in the word final position). Therefore, it could be argued that deaf children would find it easier to process the vowel as part of the head of the syllable (i.e. initial phoneme/s plus the vowel) rather than when it is combined with the coda. In our rhyme test the children could have focused only on the vowel. We have no information to show that they were perceptually aware of the shared coda or whether they processed the rime unit (i.e. vowel plus coda) as a whole. Future studies of PA in deaf children should include measures to compare head awareness and rhyme awareness.

Understanding Phoneme Awareness

More longitudinal research is needed in order to investigate the extent to which deaf children using implants can achieve true phoneme awareness. Specifically, measures should be used which assess phoneme awareness in all positions in the syllable. In addition to this, phoneme assessments could be designed to probe the differences between perceptual ability and representational adequacy. Initially, this investigation would be suitable for a case study design. Ideally, the experimenter would work in collaboration with clinicians in the implant centres. Information from audiological scientists about individual perceptual abilities could be used to design unique word sets for specific children. Phoneme tests should include trials that are **perceptually easy** and trials that are **lexically easy**. This could be achieved by targeting awareness of phonemes that are easy for the child to hear (based on specific information from audiologists). Lexically easy trials could target awareness of phonemes that should be well represented due to lexical factors (i.e. early acquired words, many phonological neighbours etc). The phonemes targeted in these trials should be ones that are **not** easy for the child to perceive. If representation of phonemes is critically dependent on auditory perceptual ability and not determined by lexical factors, then there should be a clear disparity between the trial types.

Understanding the relationship between phonological awareness and reading

We need to establish the significance of phonological awareness and reading for deaf children. Is this association mediated by the relationship between language and reading or is phonological awareness independently causal in reading outcomes for deaf children? In order to test this a longitudinal study that includes larger numbers of participants to support the use of correlation analyses should be undertaken. If phonological awareness is critically important for reading development then we need to investigate the best ways of developing these skills in deaf children. The findings from the early part of the longitudinal assessment could inform a training study to be included later as a component of the longitudinal investigation. This training should focus on the efficacy of different teaching strategies in supporting the development of rhyme and phoneme awareness. In addition, the training study could investigate the efficacy of using orthographic analogy to aid word reading.

Understanding the linguistic determinants of phonological awareness

More research is needed which directly investigates the role of language acquisition in determining the degree to which lexical representations are segmentally structured. In addition to the lexical restructuring hypothesis, Locke's theory about the sensitive period for vocabulary acquisition being critical for the development of an analytical linguistic system also warrants further investigation. Future studies should focus on the role of language acquisition in the development of phonological awareness. The PA tests could be adapted so that they were direct measures of the child's own phonological representations and the range of measures could be broadened to include tasks that assess the impact of lexical characteristics on phonological knowledge. For example, De Cara and Goswami (submitted) developed a same-different rhyme judgement task that probes the effects of rime neighbourhood density on rime processing. This test could be adapted to allow picture presentation of the items. In addition to including larger numbers of deaf participants, hearing children should be matched on **language age** to deaf children and where possible hearing children should also be matched on degree of **language delay**. If it is shown that language acquisition is a determinant of phonological awareness in deaf children this would support the lexical restructuring theory which says that phonological awareness is the by-product of a developing linguistic system. In the field of deafness research it would also have important implications proving that the development of a phonologically structured lexicon is partially **independent of sensory input**.

Finally

Think of a word .... *'phonology'*.

Phonology can be acquired through the visual, kinaesthetic and auditory modalities. Phonological awareness is not solely dependent on what is heard with the ears or seen with the eyes, but develops as a result of language acquisition. Language can be acquired through the visual, kinaesthetic and auditory modalities. One of the biggest barriers for anyone who attempts to assert a role for phonological awareness and reading in deaf children is to overcome the traditional associations that educators make when they think of the word phonology. They think of ears and mouths, they think aural oral, they often think impossible!

It has been shown in this thesis that it is **not impossible** for even very young profoundly deaf children to show some degree of phonological awareness. Clearly we need to understand more about the determinants of phonological awareness in deaf children, we need to know more about the strength of the relationship between it and reading. Above all, if research is to benefit deaf children we need to continue to clearly communicate that hearing does not equal phonology, phonology does not exist without language, profound deafness does not preclude the development of a phonologically structured lexicon.

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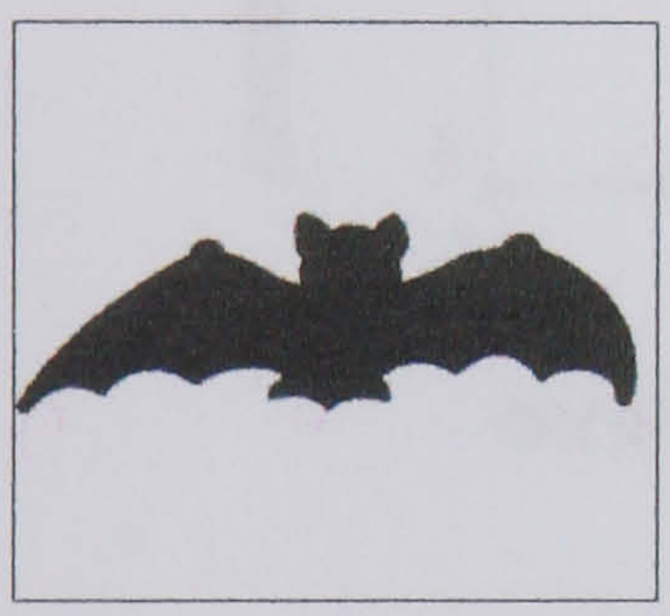
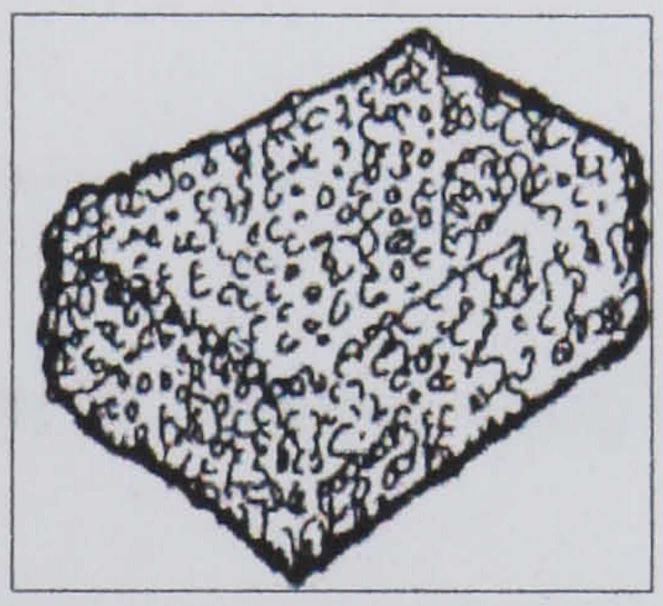
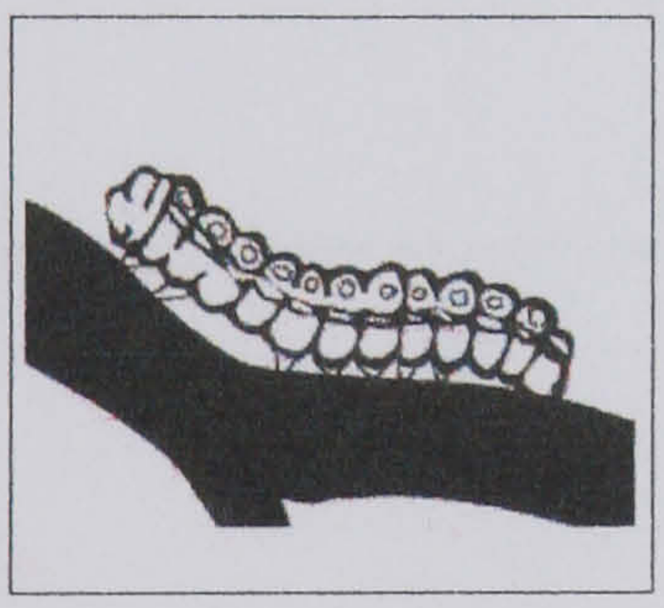
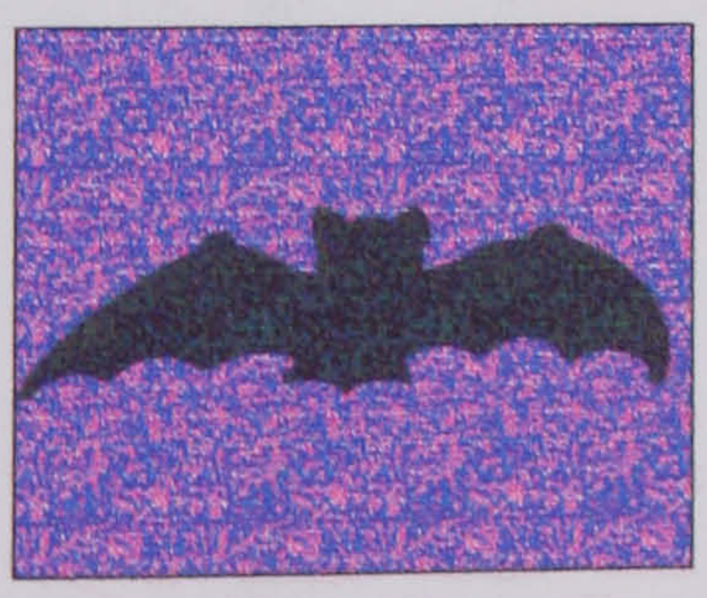
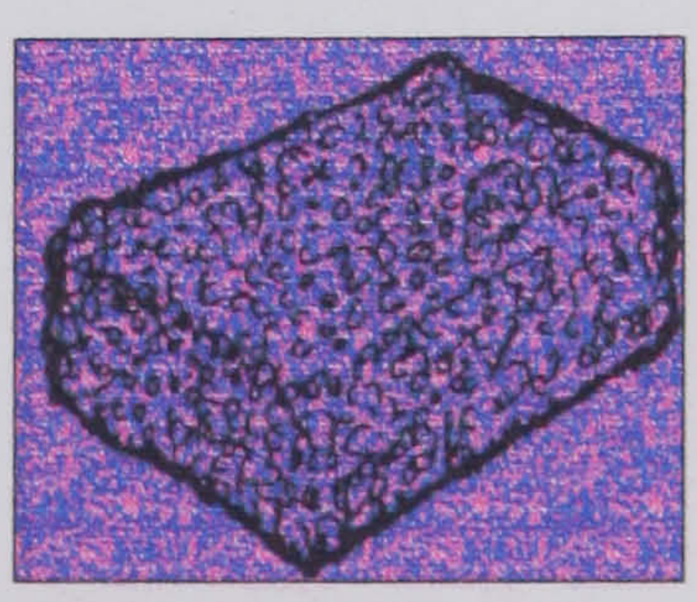
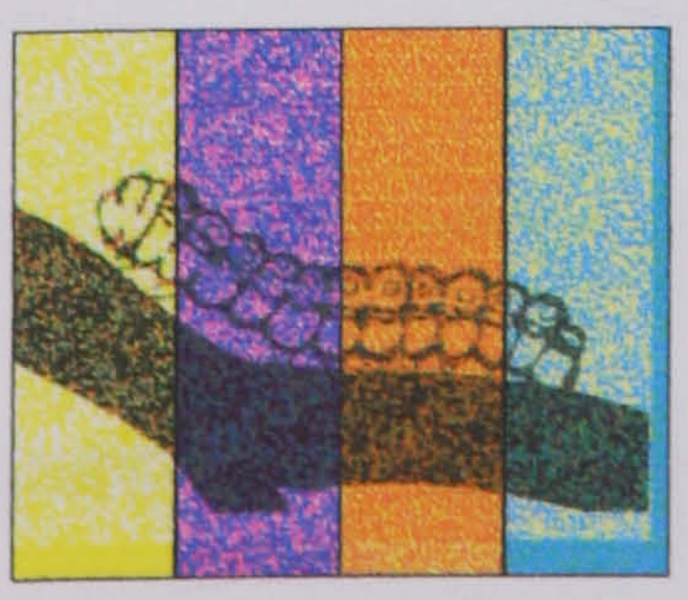
APPENDIX A

Syllable Task – Cards Used for Syllable Training

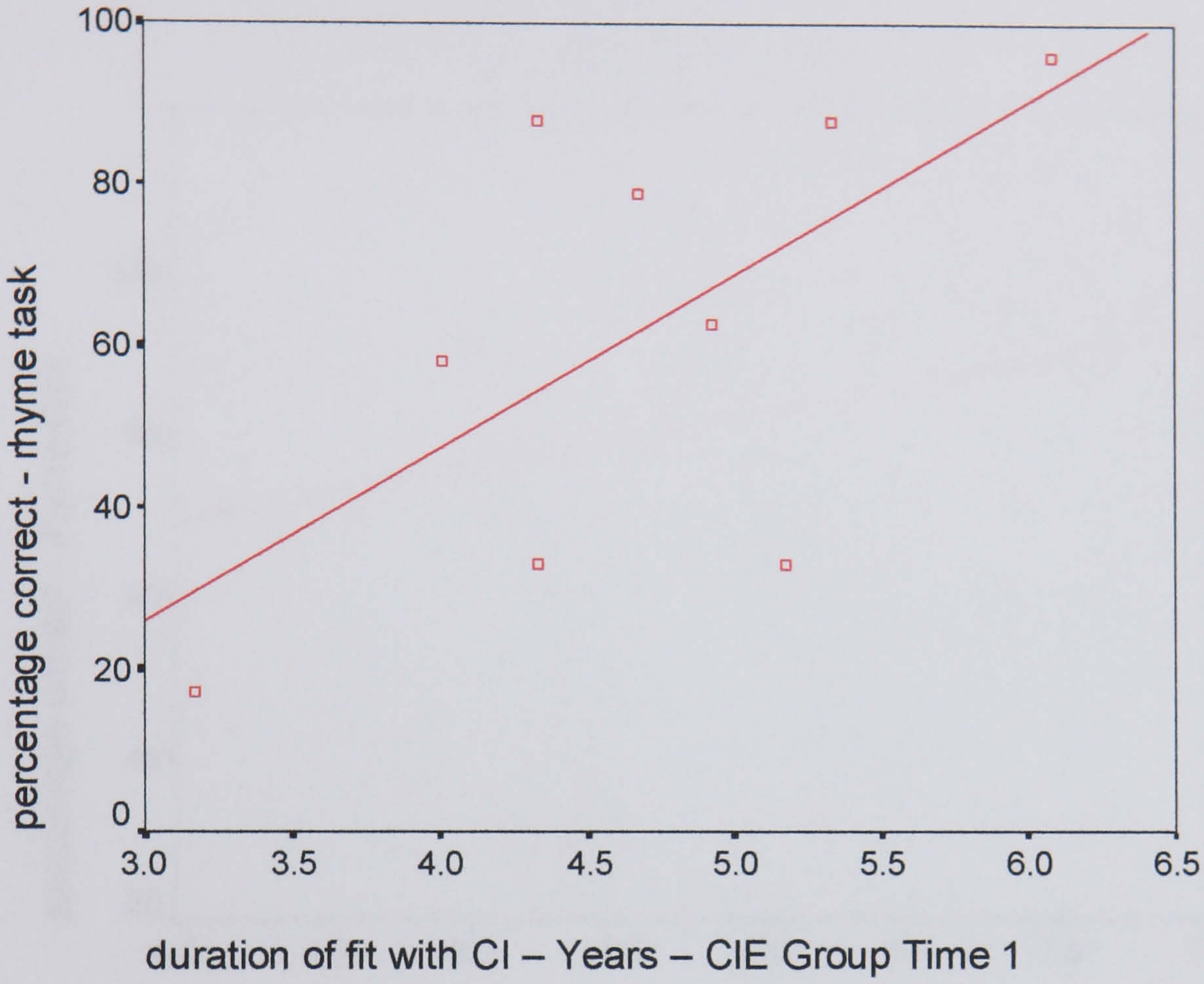
Children were presented first with the black and white line drawings. The words were named by the experimenter ('bat' 'sponge' 'caterpillar'). The children were then encouraged to clap out the syllables in the words and lift up the black and white line drawing. Underneath which was the same picture with the number of syllables represented by the coloured blocks, superimposed on the picture.

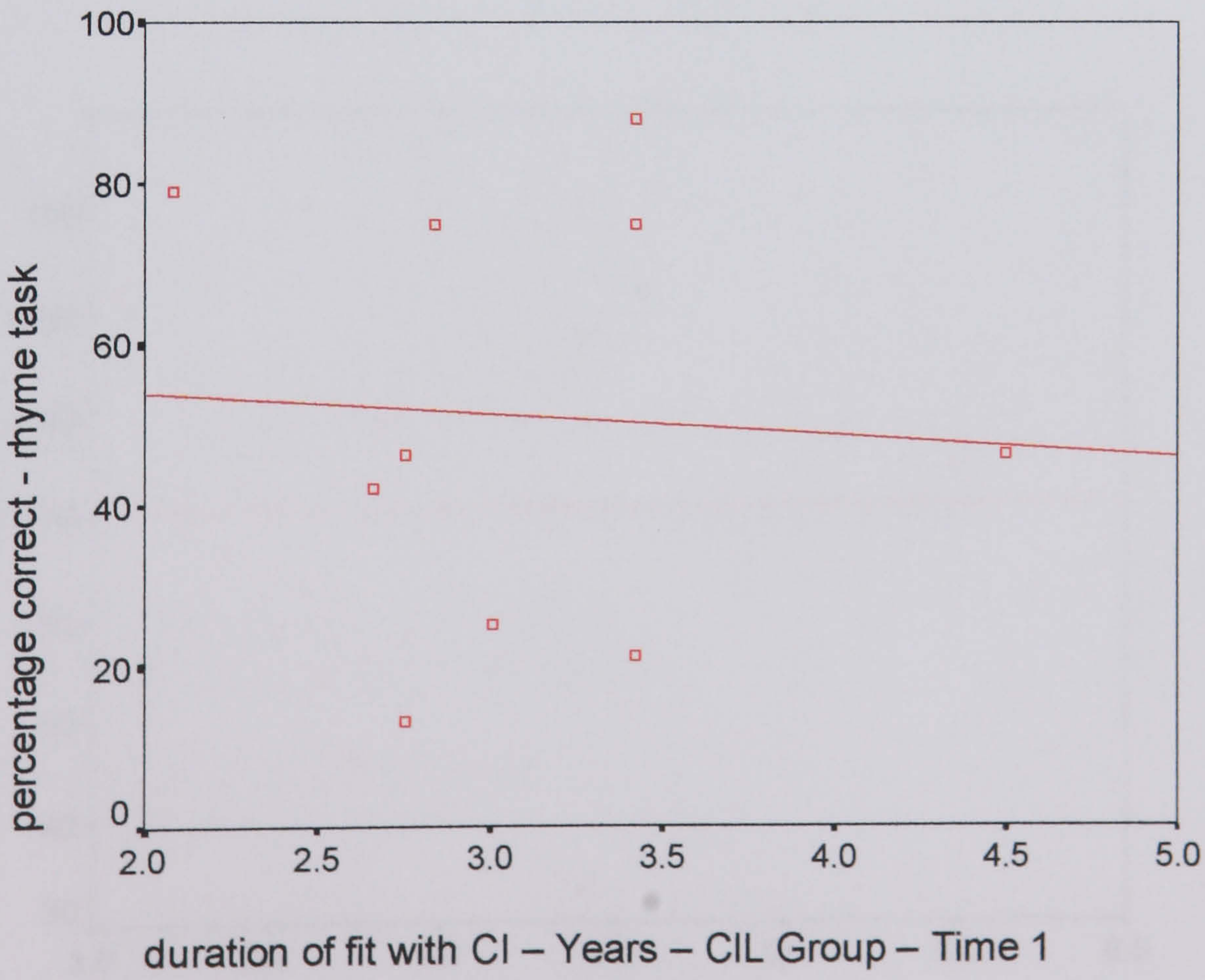




APPENDIX B

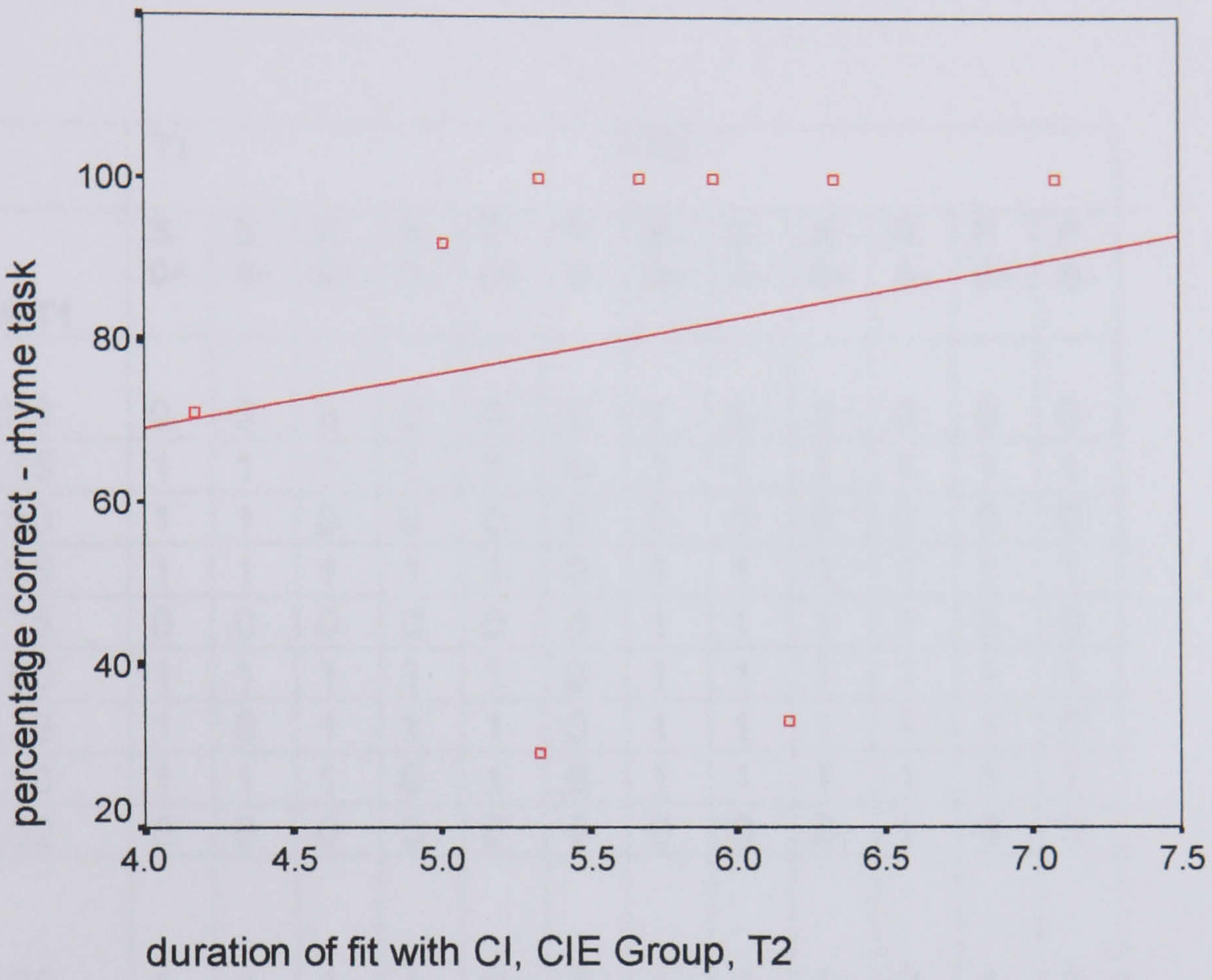
Scatter Graphs – Rhyme and Duration of Fit T1

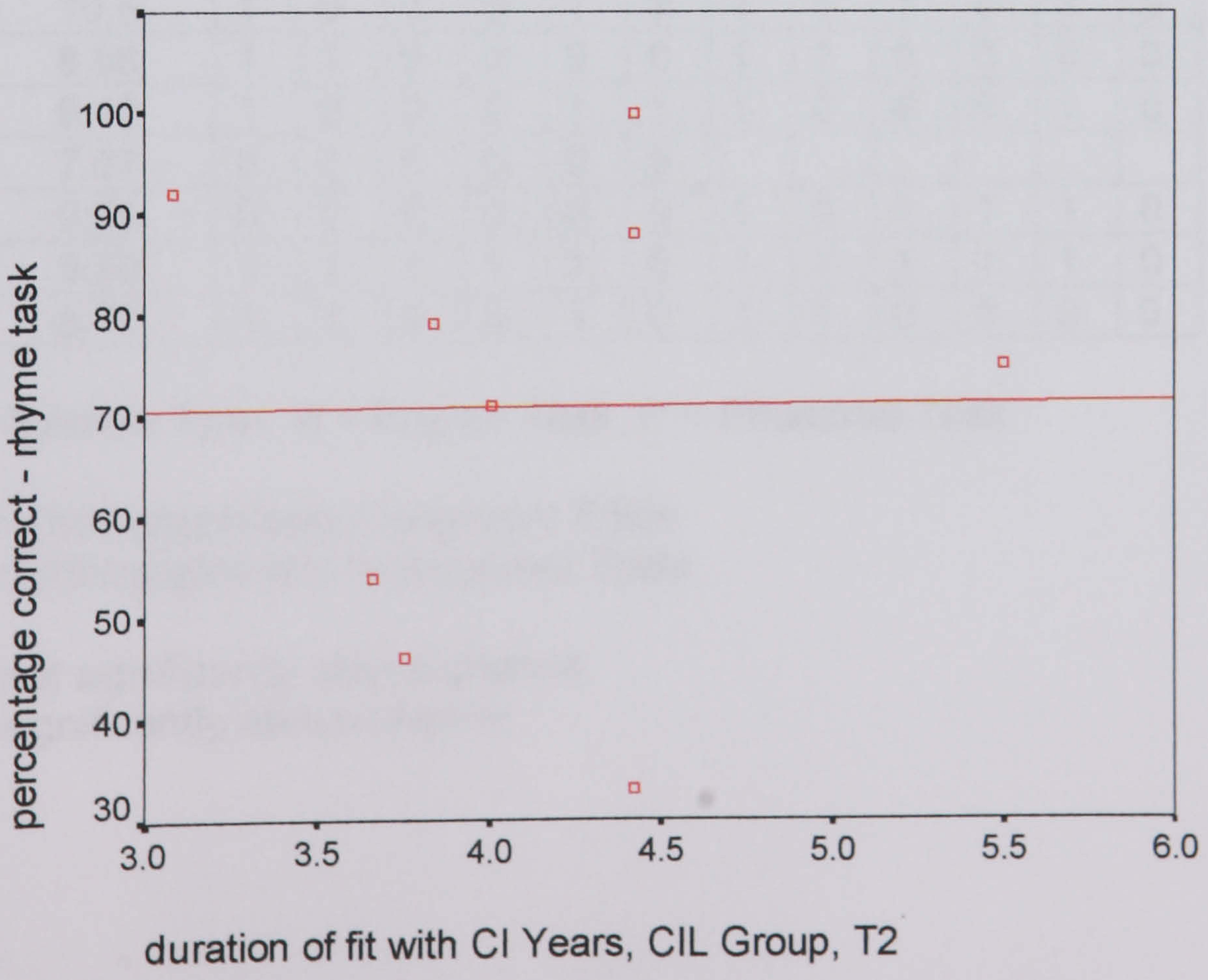




APPENDIX C

Scatter Graphs – Rhyme and Duration of Fit Time 2





APPENDIX D

Table of Pass/Fail for CI Participants on PA Tasks

Time 1 and Time 2

		T1						T2					
	CA T1	S 0+	S 0-	R 0+	R 0-	P 0+	P 0-	S 0+	S 0-	R 0+	R 0-	P 0+	P 0-
CIE													
mp	8.33	0	0	0	0	0	0	1	0	0	0	0	0
bg	7.75	1	1	1	1	1	0	1	1	1	1	1	1
bc	7.50	1	1	0	0	0	0	0	0	0	0	0	0
tf	7.58	1	1	1	1	1	0	1	1	1	1	1	1
rm	5.75	0	0	0	0	0	0	1	1	1	1	0	0
ah	7.50	1	1	1	1	1	0	1	1	1	1	1	1
aj	9.33	1	0	1	1	1	0	1	1	1	1	1	0
af	7.08	1	1	1	0	1	0	1	1	1	1	1	1
ea	6.92	0	0	0	0	0	0	0	0	0	1	0	0
CIL													
sg	9.25	1	1	1	1	0	0	1	1	1	0	1	1
hm	10.42	1	1	1	1	1	0	1	1	1	1	0	0
lp	7.67	1	1	1	1	1	0	1	1	1	1	1	1
mm	10.5	1	0	0	0	1	0	1	1	1	0	1	0
jm	8.58	1	1	0	0	0	0	1	1	0	0	0	0
dj	9.42	1	0	0	0	1	1	1	0	0	0	1	0
cb	7.67	0	0	0	0	0	0						
cc	9.25	0	0	0	0	0	0	1	0	1	1	1	0
sa	9.50	1	1	1	1	1	0	1	1	1	1	1	0
cl	8.75	1	1	0	0	1	0	1	1	0	0	0	0

S = Syllable Task, R = Rhyme Task, P = Phoneme Task

0+ = Orthographically Congruent Trials
0- = Orthographically Incongruent Trials

0 = not significantly above chance
1 = significantly above chance